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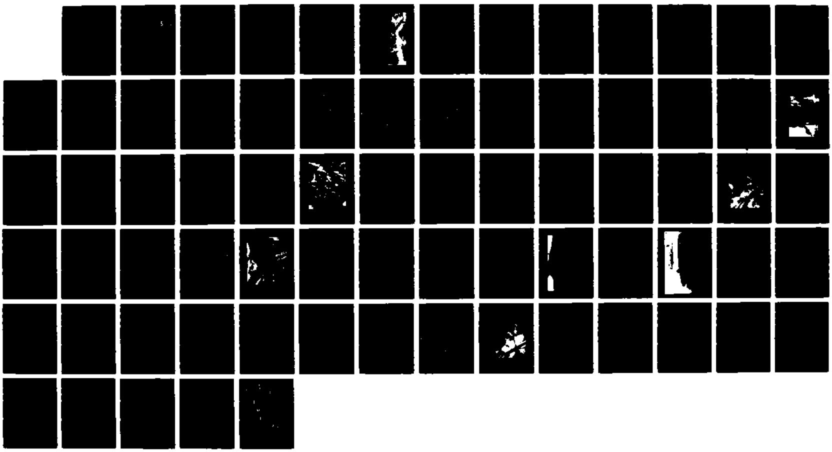

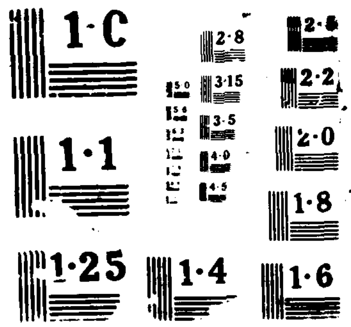
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BUHNE POINT SHORELINE EROSION DEMONSTRATION PROJECT

FINAL

MAIN REPORT

SAN FRANCISCO AND LOS ANGELES DISTRICTS
CORPS OF ENGINEERS

LOCAL SPONSOR
HUMBOLDT BAY HARBOR, RECREATION AND CONSERVATION DISTRICT

AUGUST 1987

Unclassified
SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) BUHNE POINT SHORELINE EROSION DEMONSTRATION PROJECT FINAL REPORT		5. TYPE OF REPORT & PERIOD COVERED Final, 1983-1987
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s)		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS U.S. Army Corps of Engineers, Los Angeles District P.O. Box 2711 Los Angeles, CA 90053-2325		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS U.S. Army Corps of Engineers, San Francisco District 211 Main Street San Francisco, CA 94105-1905		12. REPORT DATE August 1987
		13. NUMBER OF PAGES 1,100
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office) Federal Highway Administration P.O. Box 1915 Sacramento, CA 95809		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Beach restoration
Dune restoration
Shoreline erosion control
Native plants

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report provides detailed information on the rebuilding of the Buhne Point marine beach, the construction of retaining structures, and the establishment of native dune vegetation to prevent wind erosion. ~~The various~~ appendices ~~which are part of the~~ report thorough~~ly~~ document physical and numerical model studies done at the Waterways Experimentation Station ~~(WES) in Vicksburg Mississippi~~ for the structures and beach, as well as the post-construction and post-planting monitoring programs.
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20. Abstract, continued.

Buhne Point is located about 250 ~~air~~ miles north of San Francisco, on the east shore of Humboldt Bay, ~~Humboldt County,~~ California. A natural sand spit was located on the western face of the point, but the area lies directly in line with wind and waves entering Humboldt Bay from the Pacific Ocean. Reports of erosion there have been recorded since the mid-19th century. By the late 1970s, erosion had become so severe that the beach had disappeared, and the shoreline had eroded back to the roadway, threatening the road and underground water, gas and sanitary sewer lines. Storm waves 10' ~~in height~~ are common, and were sending rock flying across the road and against adjacent homes of the community of King Salmon.

In 1982, Congress included the area in an authorization to the Federal Highway Administration to "undertake a demonstration project to apply state-of-the-art methods for repairing damage to highways and preventing damage to highways resulting from shoreline erosion." A four-year, four-phase program was implemented, and is described in this ~~final~~ report.

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The First Phase consisted of designing and constructing a 1,250' timber groin and a 200' long rubble-mound head to prevent sand from being transported south, downcoast.

Phase II consisted of placing 600,000 yds^3 of fine-to-medium grain sand to reform the almost-24-acre beach.

In Phase III, a 1,050' shore-connected, rubble-mound breakwater was constructed on the northerly face of the beach. The Phase I timber groin and breakwater was given an additional 425' arched extension.

Phase IV consisted of vegetating the sandfill with native plants. The vegetation program included experimental collecting and growing of 20 different native and naturalized species for a two-year period, and then extensive plantings and monitoring.

Buhne Point Shoreline Erosion Demonstration Project

Final
Main Report

San Francisco and Los Angeles Districts
Corps of Engineers

Local Sponsor

Humboldt Bay Harbor, Recreation
and Conservation District

August 1987

Buhne Point, Humboldt Bay, California March 1985

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SYLLABUS

The Buhne Point Shoreline Erosion Demonstration Project was managed by the U.S. Army Corps of Engineers, San Francisco District under the authority of the Federal Highway Administration (FHWA). All phases of the project, to include that portion of the project which was funded by the California Department of Boating & Waterways, were coordinated through frequent public Steering Committee Meetings at facilities provided by the local cooperating sponsor, Humboldt Bay Harbor, Recreation and Conservation District.

Buhne Point is located in Humboldt Bay, Humboldt County, California directly across from the entrance channel jetties. Buhne Point spit was a natural sand spit that has eroded due primarily to ocean wave action that penetrates through the Humboldt Bay entrance. The erosion progressed to the point that, Buhne Drive, the main access and utility corridor to the adjacent town of King Salmon was threatened. The homes, roads and utilities in King Salmon were threatened by wave runup and flooding during storms, and wave action during high tides.

The purpose of the project was to design and construct a state-of-the-art shore protection project to protect Buhne Drive from further damage due to winter storms. Specifically, the project entailed restoring the entire eroded beach west of Buhne Drive to its historical 1955 shoreline configuration, and providing structures to maintain the configuration. The project was constructed in four phases with a two-year monitoring program.

Phase I was designed by the County of Humboldt, the U.S. Army Corps of Engineers, and the Department of Boating and Waterways. Phase I consisted of a 1,250-foot-long timber groin and a 200-foot-long rubble-mound head. The timber groin was designed to stabilize the Phase II sandfill and to prevent the material from being transported downcoast into Fields Landing Channel. Phase I was completed in December 1983.

Phase II consisted of restoring the sand spit by hydraulic dredging. The borrow areas were located inside Humboldt Bay just north of and within the middle ground channel. Approximately 600,000 cubic yards of material were dredged forming a fill of almost 24 acres. The Phase II sandfill was designed to provide the protection for Buhne Drive. Phase II was completed in May 1984.

Phase III consisted of constructing a 1,050-foot shore-connected rubble-mound breakwater on the east side, extending the rubble-mound head of the Phase I timber groin by 425 feet on the west side, and providing a rock revetment to stabilize the Phase I timber groin. Four model studies, two physical and two numerical, were used to test the proposed design and develop the alignments of the Phase III structures. The model studies were conducted at the Waterways Experiment Station (WES) in Vicksburg, Mississippi. The Phase III structures were designed to shelter and stabilize the sandfill on a long term basis. Phase III was completed in March 1985.

Phase IV consisted of revegetation of the sandfill, and a 2-year intensive monitoring program. Revegetation consisted of collecting and planting native seed and sprig species over a 10-acre area. The purpose of the revegetation was to stabilize the sandfill against wind-induced losses.

Phase IV was jointly designed and implemented by the U.S. Army Corps of Engineers and the County of Humboldt.

A 2-year intensive monitoring program was developed by the U.S. Army Corps of Engineers to document the performance of the project and determine its impact on the nearshore zone surrounding the project. The monitoring program was composed of two parts: physical and vegetative. The monitoring program was designed to provide periodic update reports from which recommendations for operation and maintenance of the project were made.

Following completion of the first four phases, the County of Humboldt Department of Public Works, under contract to the California Department of Transportation, designed improvements for Buhne Drive. The design included a 40-foot wide roadway, two 5-foot sidewalks, and 1.5-foot high retaining wall. The County administered the construction of the improvements through a private contractor.

The project has performed well. The beach has been relatively stable and has provided protection to Buhne Drive, the road and utilities, and prevented flooding and storm damage to the housing area. The beach has altered its shape slightly and some minor sand loss and redistribution has occurred. The rubble-mound structures and the concrete grouting have performed well. The project has been tested under normal storm conditions but not under severe storm conditions. The vegetative planting has continued to develop and function to reduce wind-blown sand. A sand fence was installed at the north end of the beach to control wind blown sand within the wave runup zone.

PURPOSE AND SCOPE

The purpose of the Buhne Point Shoreline Erosion Demonstration Project as stated in the Project Agreement between the Federal Highways Administration and the U.S. Army Corps of Engineers, San Francisco District, was to demonstrate state-of-the-art methods for repairing damage to highways and preventing damage to highways, resulting from shoreline erosion. Specifically, the purpose was to design and construct a shore protection project to protect Buhne Drive from further damage caused by winter storms.

The purpose of this report is to document the Buhne Point Shoreline Erosion Demonstration Project. This report constitutes the final report on the project to the Federal Highway Administration. This report is presented in four volumes. The Main Report presents a description of the project detailing the major phases of the project including pertinent design and cost data. Appendices are bound in four volumes presenting the detailed design studies and reports prepared for the project.

A slide-tape presentation was prepared by the Corps of Engineers, in conjunction with this report to show the demonstration aspect of the project. The presentation briefly describes the project in a nontechnical format. The presentation is on file with the FHWA, and the Corps of Engineers, Los Angeles and San Francisco Districts, and the Humboldt Bay Harbor, Recreation and Conservation District.

AUTHORITY

In 1982, the State of California Resources Agency, under the Harbors and Navigations Code of California, (Sections 65 and 66) authorized funds in the amount of $495,000 to the Department of Boating and Waterways for the construction of a shore protection project in the vicinity of Buhne Point in Eureka, California. The Humboldt Bay Harbor, Recreation and Conservation District (HBHRCD) was named as the local sponsor. This established Phase I for the subsequent Federally sponsored project. Earlier that year, Congressman Don Clausen, a House Representative, submitted a funding request to Congress in the form of a rider on a Federal Highways Bill to conduct a shore protection project at Buhne Point.

The Surface Transportation Assistance Act of 1982, authorized the Federal Highway Administration (FHWA) to appropriate $9 million dollars from the Highway Trust Fund to construct a shore protection demonstration project in the vicinity of Buhne Point. In June of 1983, the Federal Highway Administration, through Memorandum of Understanding (MOU) DTFGH1-83-Y-30024 authorized the Corps of Engineers to "...assume charge of the project, and take all steps necessary to accomplish the design and construction of a shoreline protection facility at Buhne Point, Humboldt Bay, California." This established Phases II through IV of the Buhne Point project.

In August of 1983 an agreement was signed between the Corps of Engineers, representing the United States of America, and the Humboldt Bay Harbor Recreation and Conservation District (HBHRCD). This established HBHRCD as the local sponsor for the project. (See Appendix A for text of the MOU and the Project Agreement).

PRIOR STUDIES AND REPORTS

The following reports have been written concerning the erosion problem in Humboldt Bay. The reports are listed in chronological order:

a. Humboldt Harbor and Bay, California. 7 March 1930. Recommended no action.

b. Humboldt Harbor and Bay, California. 5 June 1933. This review studied the effects of the jetties on the erosion of Buhne Point. The recommendation was unfavorable.

c. Humboldt Bay, California. 23 October 1950, contained in H. Doc. No. 143, 82nd Congress, 1st Session. This was a survey on the effects of erosion on Point Humboldt. No improvement was recommended.

d. Final report to the legislature by the Senate Interim Committee on Beach Erosion (Senate Resolution #39). This report presented a transcription of testimony received by the Senate Interim Committee at a hearing held August 16, 1954.

e. Beach Erosion Control Report on Cooperative Study of Humboldt Bay (Buhne Point), California. 5 October 1956. This detailed project report recommended protective measures for Buhne Spit, but no project was implemented due to lack of local funding.

f. <u>Views and Recommendations of the State of California on Proposed Report of the Chief of Engineers, Department of the Army, on Beach Erosion Control Report of Humboldt Bay (Buhne Point), California</u>. July 15, 1957. This report contains the comments of the Department of Water Resources, Department of Natural Resources, Division of Highways and County of Humboldt on the above mentioned report.

g. <u>Appendix VI, Humboldt Bay (Buhne Point), California</u>. Beach Erosion Control Study, H. Doc. No. 282, 85th Congress, 2nd Session, 24 July 1957. This study examined protection measures and solutions to the erosion problem at Buhne Point. The recommendation was to build a 800-linear foot rubblemound seawall and a 790-linear foot groin, but due to local inability to cost-share, the project was never implemented.

h. <u>Corps of Engineers Reconnaissance Report for Beach Erosion Control in the Buhne Point/King Salmon Area, Humboldt County, California</u>. 18 May 1979. This report presented and evaluated proposed solutions to the erosion problem. No further action was recommended due to lack of local funding.

i. <u>The History of Erosion at King Salmon-Buhne Point From 1854 to 1982</u>. March 26, 1982. This report is contained in the Humboldt Bay Symposium, held on March 26, 1982. This report contains a detailed history of the changes in the shoreline at Buhne Point.

j. <u>The History of Erosion at King Salmon-Buhne Point, Humboldt Bay, California from 1851 to 1985</u>. February, 1985. This report was prepared for the Corps of Engineers by the Natural Resources Division of Humboldt County and accompanied a series of eighty-four 35mm slides, copies of which were provided to the Corps of Engineers. This report detailed the historical changes which occurred at Buhne Point for approximately 130 years.

PROJECT AREA DESCRIPTION

Location

Buhne Point is located in Humboldt Bay, a natural harbor on the coast of northern California, about 200 miles north of San Francisco. Humboldt Bay is 14 miles long, and from 1/2 to 4 miles wide. The bay is separated from the Pacific Ocean by two long, narrow sand spits. The entrance to the bay is protected by two rubble-mound jetties, built by the Corps of Engineers in the late 1880's and modified since. (See Figures 1 and 2.)

Three miles south of the city of Eureka, and directly opposite the entrance to the bay is Buhne Point, sometimes called Red Bluff or Point Humboldt. The project area is a sand spit known as Buhne Spit, which lies directly southwest of Buhne Point. Directly to the east of Buhne Spit lies the small community of King Salmon. Buhne Drive is the bayside boundary between the Spit and King Salmon. (See Figure 3.)

The community of King Salmon centers on commercial and sport fishing facilities and coastal recreation, and is comprised of over 200 homes. Many of the residents have moorings in King Salmon Harbor. The community was developed in 1947, with the fishing facilities developed in 1949.

Directly north of Buhne Spit is the Pacific Gas and Electric Co. (PG&E) Humboldt Bay Power Plant. To the north of the plant is the Elk River Spit which extends for about 3 miles. Directly south of Buhne Spit is Fisherman's Channel, the cooling water intake for the PG&E plant. Fisherman's Channel is also the entrance to King Salmon Harbor.

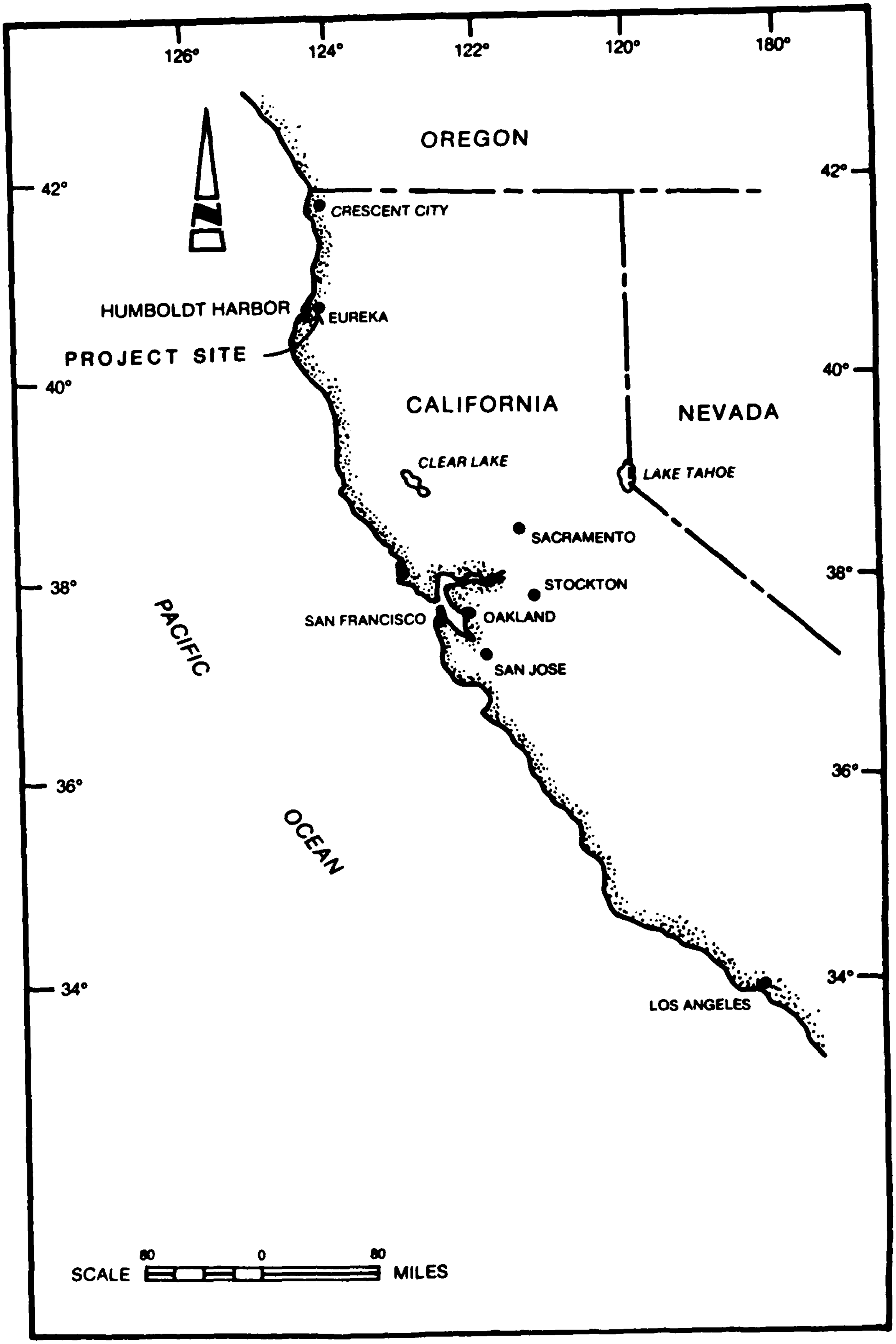

Figure 1. General Location Map

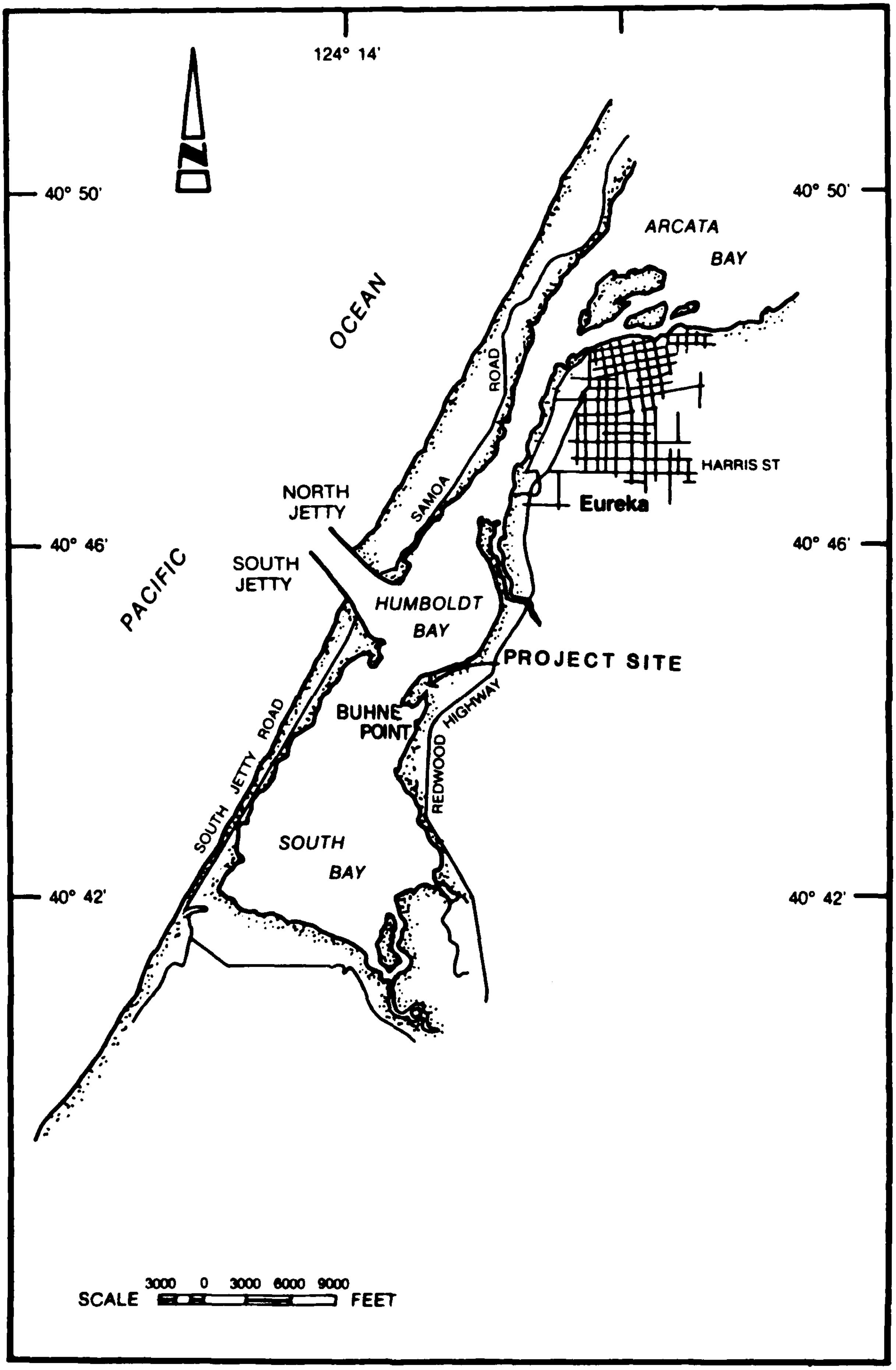

Figure 2. Humboldt Bay

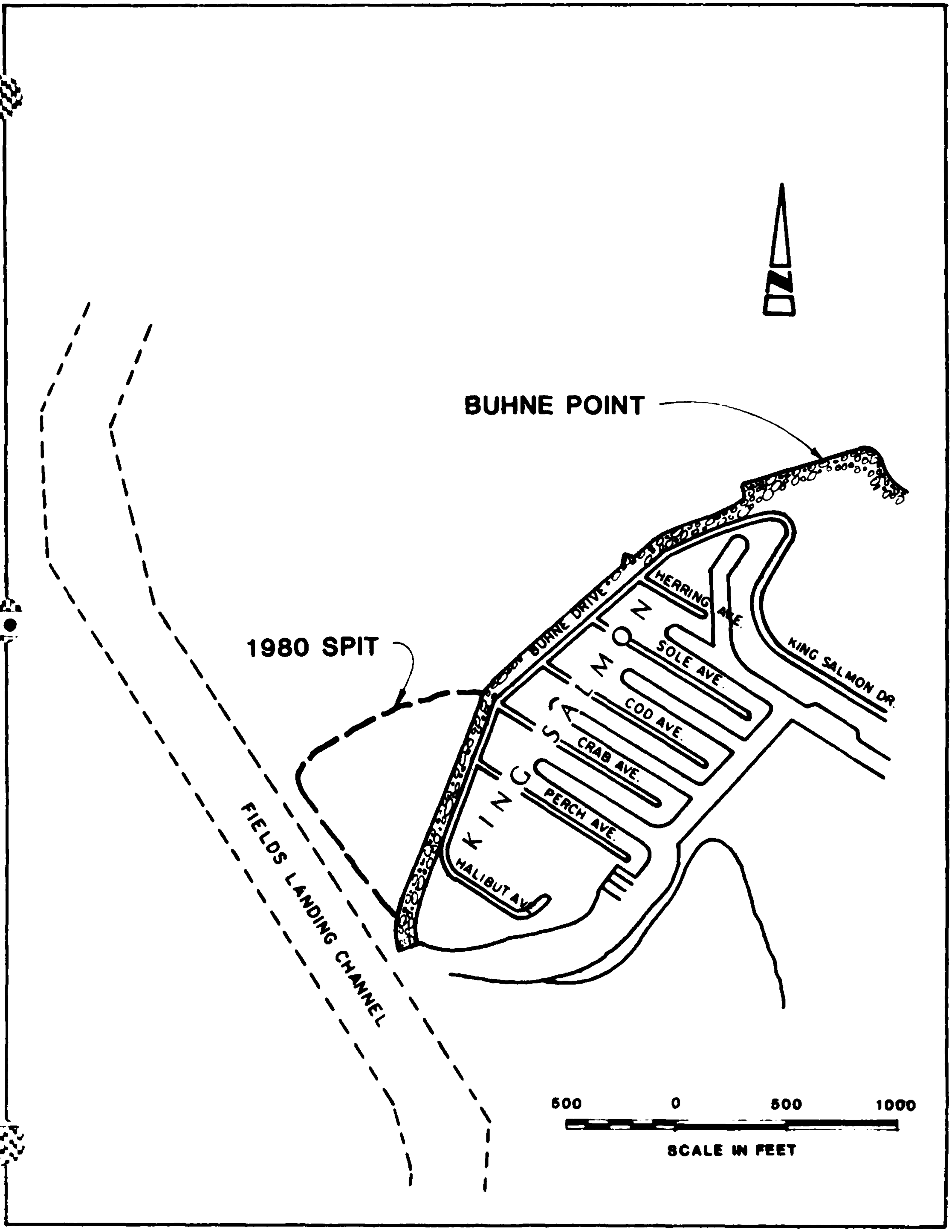

Figure 3. Project Area - 1980 Buhne Spit Configuration

Shore Ownership

The shore area of Humboldt Bay is primarily in private ownership except for the Federally owned land on the North and South spits. Much of the shore area of the South Bay is within the Humboldt Bay Wildlife Refuge. The developed areas to the south of Buhne Point are used for shipping and lumber facilities. Elk River spit is undeveloped and owned by the City of Eureka. The shoreline property between Elk River Spit and the PG&E power plant is owned and maintained by the Eureka Southern Railroad Company Inc., which provides service to and from Eureka. For the purpose of the project, most of the Buhne Point area was considered to be privately owned. The project area was owned by the Eureka Shipbuilders Inc. Title to the property, however, was subsequently transferred to the Humboldt Bay Harbor, Recreation, and Conservation District along with a portion of PG&E land downcoast of Buhne Point in 1984.

Weather

Humboldt Bay is exposed to Pacific Ocean storms characterized by high winds and tides. This area experiences considerable precipitation as well. Average seasonal precipitation totals approximately 40 inches per year. Air and water temperature are stable and generally cool or cold. Water temperatures range from 50 degrees F in January to 59 degrees F in August. Mean air temperatures range from 47 degrees F in January to about 62 degrees F in September. Prevailing winds are from the north and northwest during the summer and from the north and southeast during winter. Windspeeds range from 4 to 18 miles per hour, with the greatest wind velocity recorded being 56 miles per hour.

EXISTING CORPS PROJECTS

Entrance Jetties

An understanding of jetty construction on Humboldt Bay at the entrance is necessary because of the close correlation of the effect of the jetties on the erosion of Buhne Point. The alignment of the jetties was such that it focused wave energy from the Pacific Ocean to enter the bay between the jetties and attacked Buhne Point, which was at an elevation of 100 feet, approximately 1,400 feet west of its present location.

The Corps of Engineers recommended in 1883 that the entrance to Humboldt Bay be improved with a 6,000-foot-long jetty on the south spit. Construction of a jetty on the north spit was subsequently recommended in 1891. Both jetties were completed in 1899.

By 1907, both jetties had become ineffective as they had been buried by channel shoaling. From 1914 to 1925, the jetties underwent reconstruction. Since 1925, both jetties have undergone many construction-repair cycles.

In 1985, the Corps of Engineers completed a comprehensive condition survey of the jetties at Humboldt Bay and Crescent City. A complete history of the Humboldt Jetties is included therein, and may be referred to for further details.

The existing north jetty is 7,400 feet long and is a rubble-mound structure. It has a 20-foot by 2-foot concrete slab running along its entire length, at a crest elevation of +16 feet MLLW, with a concrete and rock parapet extending to +20 feet MLLW. The parapet ends in a 1,050-ton concrete monolith. The jetty head has a crest elevation of +26 feet MLLW.

The south jetty, 2,600 feet south of and parallel to the north jetty, is also a rubble-mound structure and extends for 8,990 feet. A 20-foot by 2-foot concrete slab runs along the length of the jetty ending in a 950-ton concrete monolith at the seaward end of the jetty. The jetty head also has a crest elevation of +26 feet MLLW.

Maintenance Dredging

Dredging began in 1883 in Humboldt Bay in the Hookton Channel. Dredging was necessary as shoaling had occurred due to the erosion of Buhne Spit from 1854 to 1903. Prior to 1950, the dredge material was disposed within Humboldt Bay. The principal disposal areas were (a) in deep water at the bayward end of the entrance channel; (b) in deep water west of the northern end of Fields Landing Channel; and (c) in deep water near Fairhaven. In 1938, King Salmon was delineated as a disposal area, and approximately 80,229 cubic yards were placed there. Between 1915 and 1950, almost 3 million cubic yards were disposed in the bay. For comparison, almost 5 million cubic yards were eroded from the Buhne Point area between 1859 and 1952. Since 1950, all dredged material has been deposited in deep water in the Pacific Ocean.

Annual dredging has been necessary to maintain the Entrance Channel and Fields Landing Channel. The Entrance Channel is currently maintained at a depth of 40 feet, and is 500 feet wide with a flare to 1,600 feet wide. Fields Landing Channel is currently maintained at a depth of 26 feet, and is 300 feet wide.

STATEMENT OF PROBLEM

Buhne Point and Buhne Spit have had a long history of erosion. Wave energy entering through the Humboldt Bay Entrance impinges on Buhne Spit and has created severe erosion of the Spit and shoaling of the navigation channels. In the last decade, the erosion had removed all of the beach thereby exposing Buhne Drive to direct wave attack. Buhne Drive is the only public access road into King Salmon, and contains vital underground utilities (i.e., water, gas, and the main sanitary sewer line). The PG&E power plant was also threatened due to the eroded material from Buhne Spit depositing into their cooling water intake channel.

The County of Humboldt accepted Buhne Drive into the County maintained road system in August of 1954. In 1952, PG&E following acquisition of the property at Buhne Point, placed approximately 3,000 linear feet of rock rip-rap along their property thereby preventing erosion of the point in that year. The sand spit remained relatively stable west of Buhne Drive until the mid-1960's.

The County of Humboldt began placing rock protection along Buhne Drive in 1966. By 1982, most of Buhne Spit had eroded, and the entire bay side of Buhne Drive was revetted with large rock to protect the road and underlying utilities from destruction by wave action. PG&E in conjunction with County of Humboldt, using a $50,000 grant from California Department of Boating & Waterways, completed placement of rock rip-rap along the shoreline from end of Buhne Drive to entrance to Fisherman's Channel by December 1982. However, most of this emergency rock revetment was not designed as a permanent structure to withstand large breaking waves and consequently was overtopped during severe storms. Larger waves were breaking onto the revetment with wave runup overtopping the revetment and running onto the roadway, disrupting traffic and causing localized flooding of homes. (See Figure 4.) During severe storms, smaller rocks from the revetment were carried onto the roadway and into nearby homes, breaking windows and causing minor structural damage. An earthquake in November 1980 settled the revetment by approximately 3 feet and caused it to unravel at various locations. Buhne Drive became undermined by wave runup and collapsed in numerous locations. (See Figure 5.) These conditions created an extreme safety hazard during moderate to large storm wave conditions.

Potentially, large rocks from the revetment could have become dislodged and rolled onto the roadway, thus blocking access to King Salmon for emergency vehicles and the public. In addition, as the remaining spit receded (both horizontally and vertically), larger waves could have broken farther up onto the rock revetment, thus worsening the existing condition.

Figure 4. Waves Breaking on Buhne Drive.

Figure 5. Waves Overtopping Buhne Drive.

SHORELINE HISTORY

General

The Corps of Engineers has been periodically studying the erosion of the Buhne Point area since the early 1900's, most recently in the 1979 Reconnaissance report for Beach Erosion Control. It has been documented that the shoreline in this area has had a history of almost continuous erosion.

Before permanent structures were erected, the mouth of Humboldt Bay shifted north and south, depending on the season and ocean conditions. In the late 1880's, the position of the mouth was permanently fixed by the construction of the entrance jetties. This permanently focused the wave energy farther south on Buhne Point, thus changing the pattern of erosion. From 1880 to 1952, the shoreline of Buhne Point eroded 1400 feet east, resulting in the loss of nearly 188 acres.

Before measures were taken to protect the shoreline, Buhne Point became a nodal point for the entire shoreline area between King Salmon and the mouth of the Elk River Spit. Material which eroded between Buhne Point and the root of Elk River Spit was transported north and deposited on the spit. Material which eroded between Buhne Point and King Salmon was transported south and deposited temporarily on Buhne Spit. This material was then eventually deposited into Fields Landing Channel by wave and tidal current action.

Shoreline Changes

Prior to construction of the entrance jetties, there was little erosion of Buhne Point. Between 1854 and 1891, approximately 200 feet of the beach eroded between Buhne Point and the mouth of Elk River. However, from 1891 to

1926 following construction of the jetties and thereby stabilizing the entrance to Humboldt Bay, Buhne Point eroded another 200 feet, and from 1926 to 1955, it eroded 1,000 feet; a total of 1400 feet in 101 years.

Buhne Spit, where King Salmon was to become, also went through several changes from 1854 to 1946. From 1854 to 1903, Buhne Spit began to accrete slowly to the west. This accretion was probably a result of the increased erosion of Buhne Point between Elk River Spit and King Salmon. From 1903 to 1926, the Spit moved 600 feet to the southwest, and from 1926 to 1946, the Spit moved 400 feet west toward the Bay (See Figure 6). Of interest, there was no Buhne Spit in 1911. (Tuttle, 1982).

In 1930, the Northwestern Pacific Railroad (NWPRR) company installed 3,000 feet of rock revetment along its property to protect the railroad from waves, and to halt the erosion. In 1938, a Corps of Engineers dredging plan delineated King Salmon as a disposal site for dredged material. While little documentation of this exists, it can be seen from the shoreline changes map that Buhne Spit experienced large accretion between 1931 and 1939. It is estimated that as much as 80,000 cubic yards were deposited at this time. In 1952, PG&E bought 137 acres of land at Buhne Point and also constructed 3,000 feet of rock revetment along its shoreline property. While this protection was effective in halting the landward retreat of the shoreline north of Buhne Spit, it reduced the supply of littoral material being transported to Buhne Spit, thus accelerating erosion in the area. The area of the spit in 1956 was approximately 25 acres.

Since 1961, there has been an almost continuous rate of erosion shoreward (See Figure 7). From 1961 to 1979, the average annual rate of erosion was

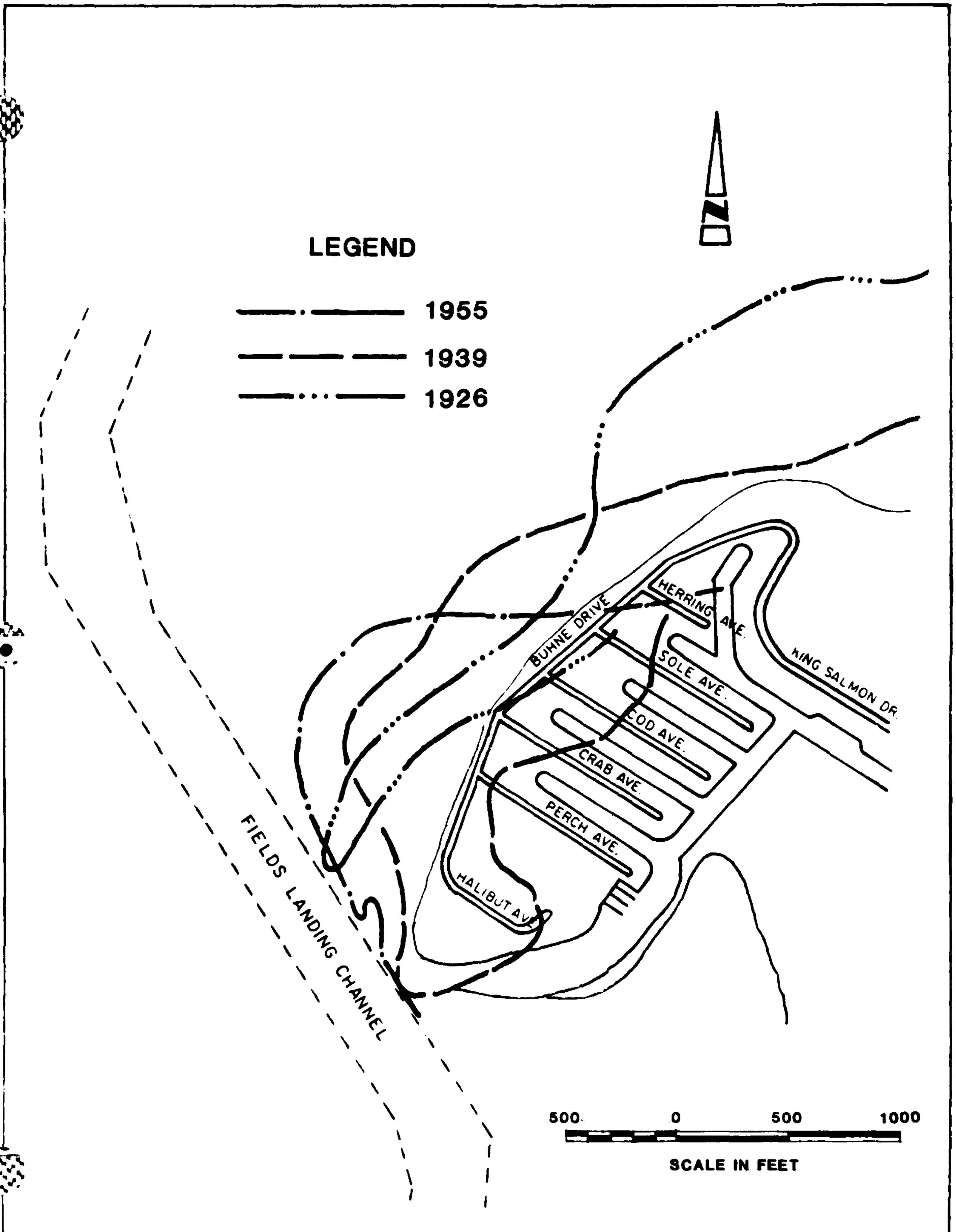

Figure 6. Shoreline Configurations - 1926 To 1955

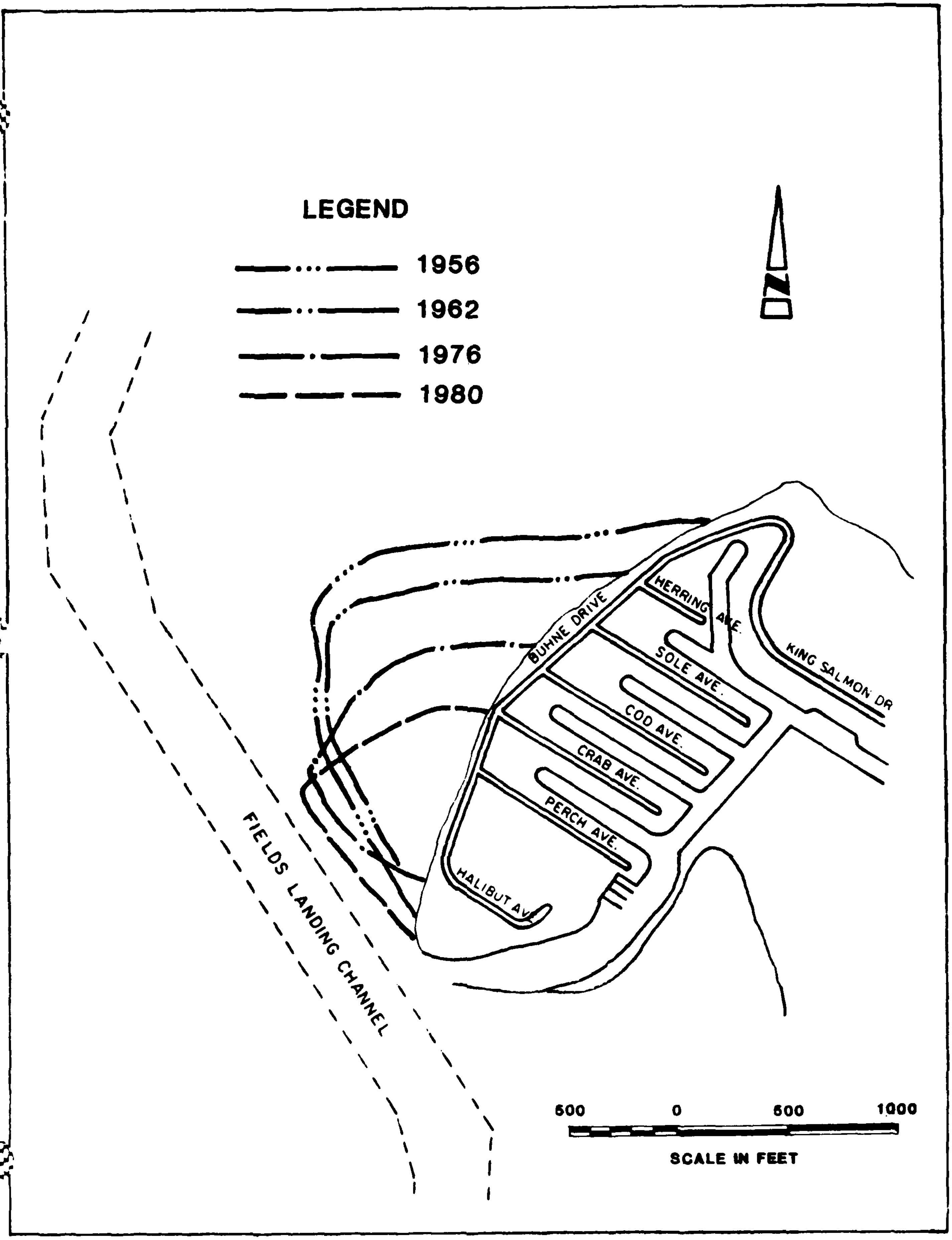

Figure 7. Shoreline Configuration - 1956 To 1980

estimated to be almost 27 feet per year. Starting in 1966, the County of Humboldt began placing riprap along Buhne Drive. As the erosion of Buhne Spit progressed, the County had to increase its rate of placing riprap in 1976 because the erosion was beginning to expose the road. By 1982, almost no spit remained at all, thus establishing the pre-project condition (See Figure 8).

Figure 8. 1982 Configuration of Buhne Spit.

PLAN FORMULATION

In 1982, the Humboldt Bay Harbor, Recreation and Conservation District approached the California State Department of Boating and Waterways to design a project to mitigate shoreline erosion at Buhne Spit, and to reduce the shoaling in Fisherman's Channel. The design report (Appendix E) was completed in May 1983 with a recommended plan consisting of a timber groin with a rubble-mound head and an offshore rubble-mound breakwater surrounding a dredged beach.

Because of the project area's proximity to Federally maintained navigation channels, it was anticipated that periodic maintenance dredging by the Corps of Engineers could provide the beachfill material. This was a critical element of the State's design because alternative methods for obtaining beachfill material would have caused the project to be too costly.

In 1983, the State of California authorized $495,000 for the State Department of Boating and Waterways to construct Phase I, the timber groin with a rubble-mound head. The Humboldt Bay Harbor, Recreation and Conservation District was the local cooperating sponsor, and the County of Humboldt was responsible for the final design and construction. It was considered that the groin, together with the beachfill, would serve as a short-term solution to the erosion problem.

Concurrent with the State's efforts to design a shore protection project, Congressman Don Clausen was working on obtaining Federal dollars for a shore protection project at Buhne Spit. The Federal Highway Administration was authorized funds in late 1982 to construct a demonstration project in the

Buhne Point area. The U.S. Army Corps of Engineers, San Francisco District, was contacted in March of 1983 to take charge of the design and construction of the project.

Using the State Department of Boating and Waterways recommended plan as a guide, the Corps of Engineers was responsible for designing the Phase II sandfill. In addition, the Corps was also responsible for determining if there was a need for Phase III long-term stabilization structures, and then designing them as necessary.

Since the design of Phase I of the project was almost complete when the Corps of Engineers began its studies, the Corps also focused its efforts on integrating the Federal project with the State project. The Corps of Engineers served in a technical capacity for the construction of Phase I by providing soil design values and the Phase I groin alignment. This insured the compatability of the State and Federal projects.

PROJECT COORDINATION

In order to maintain communication and coordination between the different agencies involved in this project, Steering Committee Meetings were established by the Corps of Engineers, San Francisco District and the FHWA. The meetings were held every other month at the HBHRC District Office, and were open to the public (See Appendix L). The meetings provided an opportunity for most project concerns and conflicts to be resolved, as well as for project progress to be discussed. These meetings assured good communication between the agencies on this project from inception to completion. The primary participants for the project included:

a. Federal Highway Administration

b. U.S. Army Corps of Engineers

    San Francisco District

    Los Angeles District

c. Humboldt Bay Harbor, Recreation and Conservation District

d. County of Humboldt Public Works Department

e. Calfiornia Department of Boating and Waterways

f. California Department of Transportation

g. Community of King Salmon

h. Pacific Gas and Electric Company

PHASE I

Plan of Study

The initial design study for Phase I of the Buhne Point project was developed by the Department of Boating and Waterways with assistance from the Natural Resources Division of the Humboldt County Department of Public Works and is presented in their 1983 report entitled "Design Study for Buhne Point/King Salmon Shore Protection Project" (Appendix E).

The report presented a detailed engineering design study of four basic types of structures: (a) offshore breakwater, (b) rubble-mound seawall, (c) rubble-mound groin, and (d) and H-pile groin with wood lagging. From these studies, twelve alternatives were formulated and evaluated on the basis of project criteria to determine the recommended plan. The final design and contract documents for the Phase I structure were developed by the County of Humboldt Department of Public Works. The foundation design and alignment were subsequently provided by the U.S. Army Corps of Engineers. Both design and foundation studies are presented in Appendix E.

Plan Selection

The recommended Phase I structure from the Department of Boating and Waterways report consisted of a 1400-foot-long H-pile timber groin with a rubble-mound head. The groin was accepted by the U.S. Army Corps of Engineers as the selected plan, and no additional alternatives were considered. The Phase I recommended plan was modified by the County of Humboldt in coordination with the Department of Boating and Waterways.

Soil design values were provided by the U.S. Army Corps of Engineers in the Phase II Foundation Report prepared in June 1983 (Appendix E). The final alignment of the timber groin and rubble-mound head were also provided by the U.S. Army Corps of Engineers, based on calculations to maximize the sandfill area while retaining protection features.

Selected Plan

It was determined during initial Steering Committee Meetings that the State's funding amount of $495,000 would be insufficient to construct both the groin and the rubble-mound head. It was decided that the construction of all rockwork for Phase I would be added to the construction of the Phase II sandfill, and the cost would be covered under the FHWA funds. Figure 9 shows the Phase I structure; Figure 10 is an aerial photograph of the structure after completion of construction.

The groin ties into the existing stone riprap along Buhne Drive at Halibut Street. The groin extends for 1,000 feet generally paralleling the existing Fields Landing Channel. For the final 250 feet, the timber groin curves eastward at a radius of 600 feet. The steel piles (HP 12 x 53) were spaced approximately 8 feet apart. The wood lagging was pressure treated 4-inch by 12-inch Douglas Fir. A steel wale was added to the downcoast side of the timber groin to increase the structural stability. The wale was an additive to the construction contract. The crest elevation of the timber groin was constructed at +11.0 feet MLLW. Filter fabric was also provided under the bedding layer on the downcoast side of the groin to prevent sand migration through the structure.

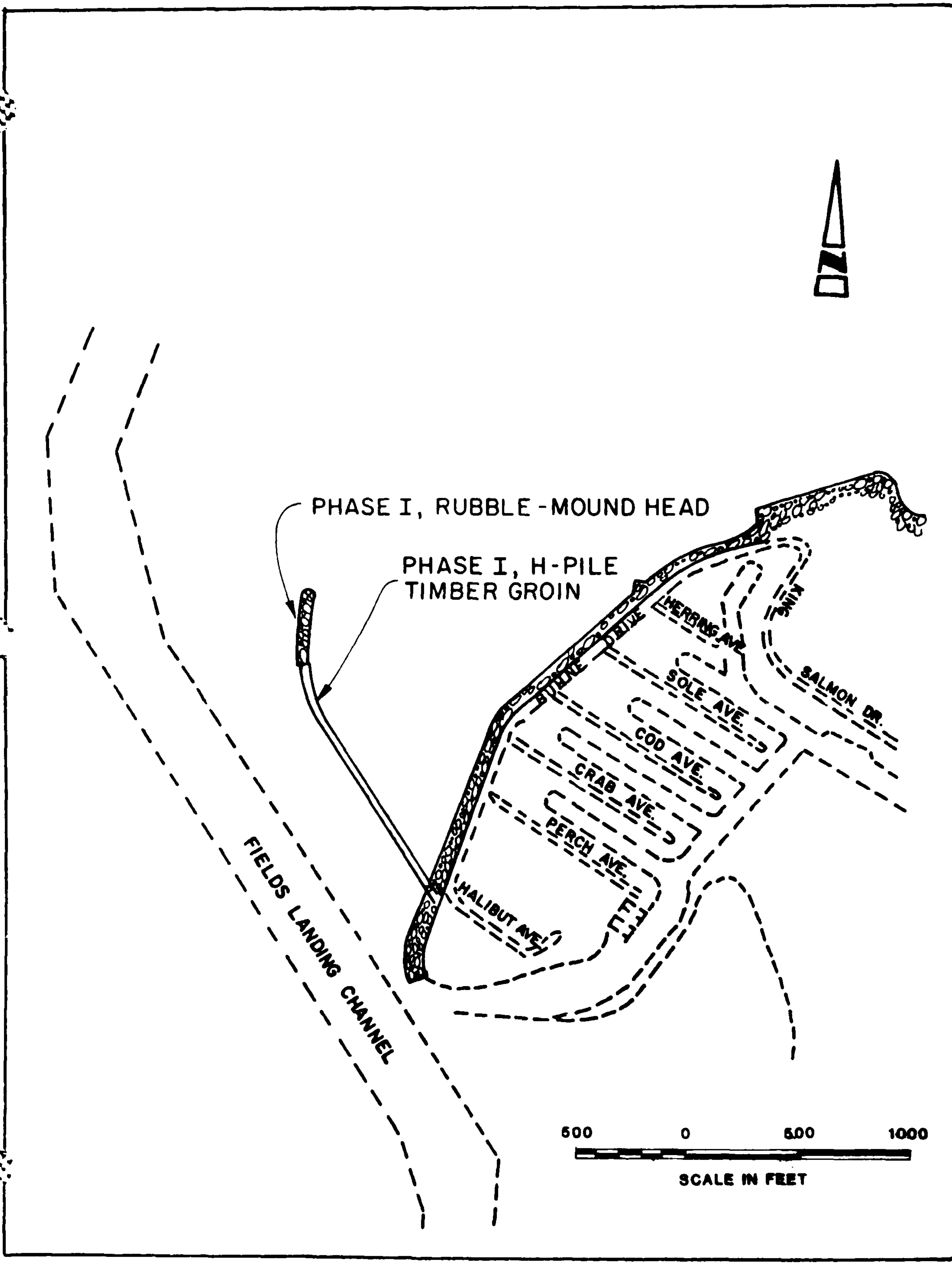

Figure 9. Phase I General Plan

Figure 10. Phase I Aerial March 1984.

The rubble-mound head extends 200 feet long and begins 50 feet before the end of the timber groin. The head curves eastward at a radius of 600 feet. The head construction consists of a 5-foot layer of 4-ton rock slope protection over a quarry waste core and a bedding layer two feet thick. The toe protection consists of 1-ton and 4-ton rock. The crest elevation of the rubble-mound head was constructed at +11.0 feet MLLW.

PHASE II

Plan of Study

The design study for Phase II was conducted by the Corps of Engineers, Los Angeles District. The purpose of Phase II was to utilize existing borrow areas within the bay to design a sandfill that would provide protection to Buhne Drive. The borrow area was located inside Humboldt Bay, adjacent to the North Bay Channel. This area is currently dredged on a regular basis by the Corps of Engineers, San Francisco District for maintenance purposes.

The design studies for Phase II were focused on two objectives:

1. Determine through soils analysis, the suitability of the borrow area material for project purposes.

2. Design a sandfill configuration to maximize protection to Buhne Drive.

Design details and Basis for Design are included in Appendix E.

Selected Plan

Based on the design studies for the sandfill, it was determined that the borrow area material was suitable for a sandfill at Buhne Drive. The borrow area was delineated as approximately 4000 feet long by 400 feet wide. (See Figure 11.) The average distance from the borrow area to the sandfill was approximately 1.2 miles. The material in the borrow area was excavated by hopper dredge as wave conditions were too rough for suction or cutterhead dredges. About 600,000 cubic yards were dredged from the borrow area by a

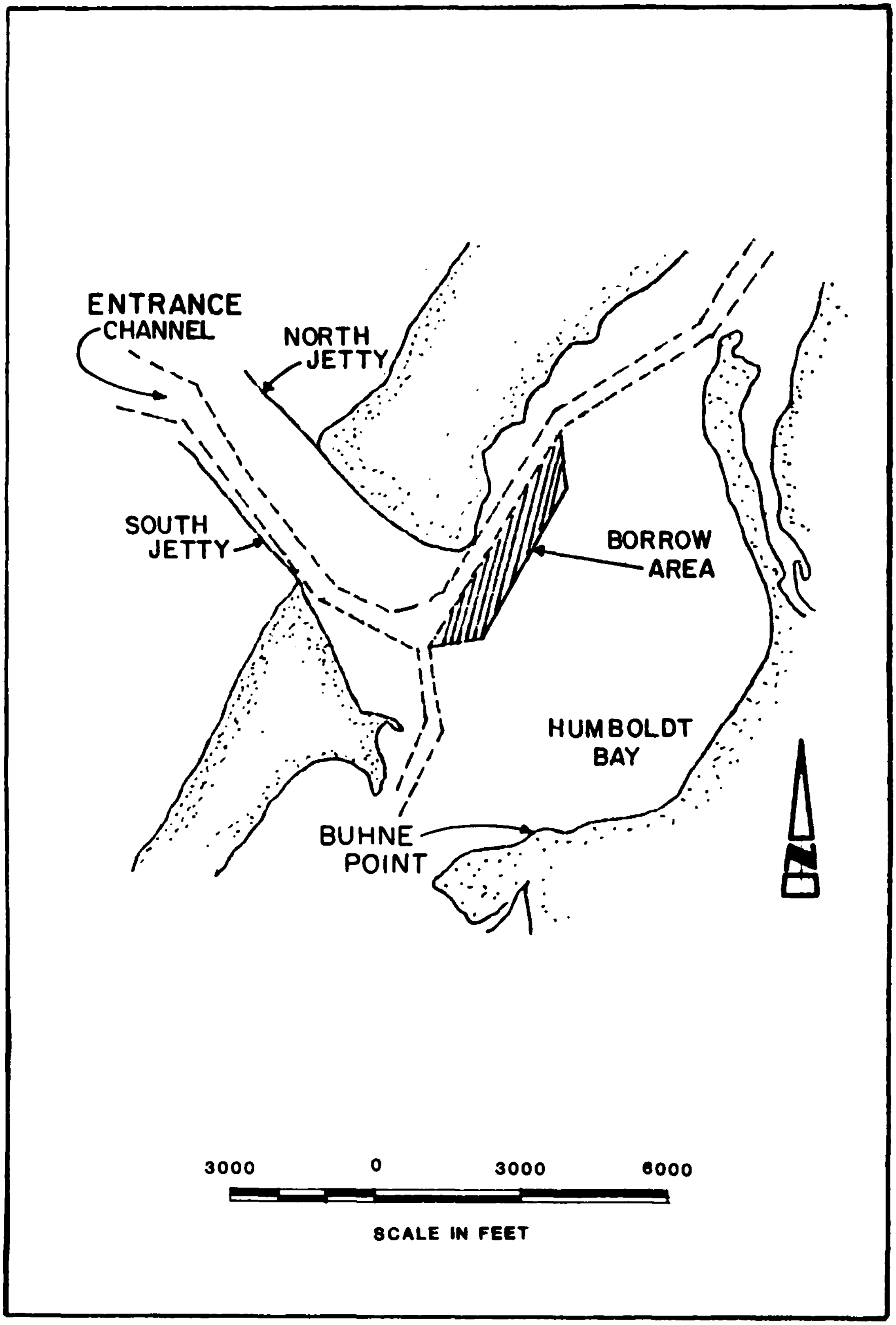

Figure 11. Phase II Borrow Area

hopper dredge and deposited in open water near the project site where the material was pumped by a hydraulic suction dredge and moved onto shore. The material was placed from the upcoast end to the downcoast end of the timber groin.

The sandfill was placed in a triangular configuration. (See Figure 12.) The western side was bordered by the Phase I timber groin, and the eastern side was bordered by Buhne Drive. The sandfill extended from Halibut Street to King Salmon Drive. An aerial photograph of the Phase II project configuration is shown in Figure 13.

To minimize erosion losses, the crest elevation of the sandfill was set at +15 feet MLLW, which was spread out to +12 feet MLLW during Phase III. The seaward slope of the sandfill was constructed one vertical to 10 horizontal, which reached equilibrium at one vertical to 10 horizontal. The construction slope of the sandfill at the groin was one vertical to 3 horizontal, which is approximately the angle of repose of the sand material. The elevation of the sandfill at the timber groin was approximately about +11 feet MLLW.

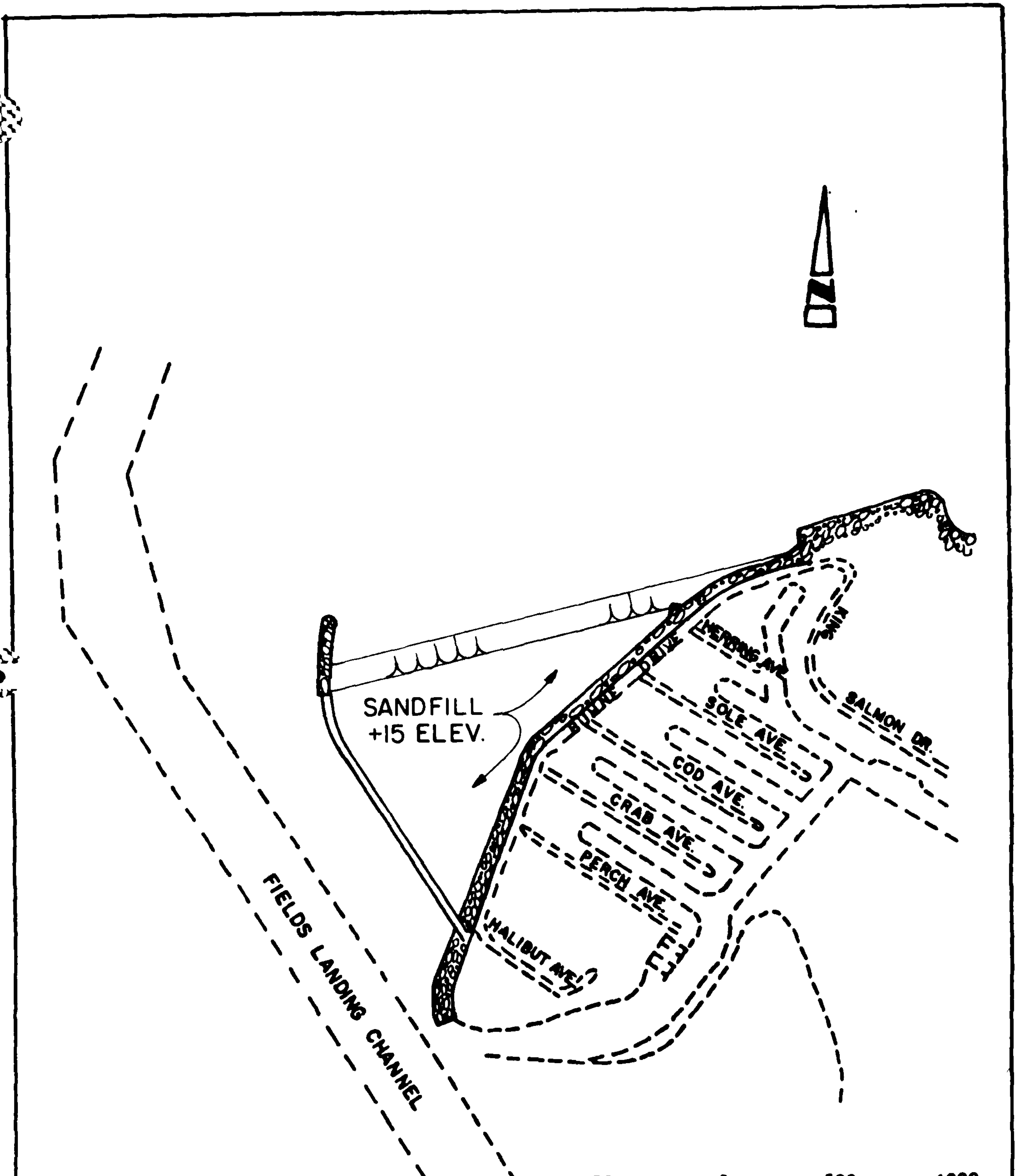

Figure 12. Phase II General Plan

Figure 13. Phase II Aerial August 1984.

PHASE III

Plan of Study

The design and alignment of the Phase III structures were determined by the U.S. Army Corps of Engineers, Los Angeles District and the Waterways Experiment Station (WES) in Vicksburg, Mississippi. The purpose of Phase III was to develop and construct additional structures in the Buhne Point area, as necessary, to provide long-term protection to the Phase II project.

The Corps of Engineers enlisted the help of WES to determine, through the use of model studies, the hydrodynamics of the project area, and to use this information to evaluate the effectiveness of various structures. The model studies were then used to develop final alignments and elevations. The engineering design studies are presented in Appendix F.

Model Studies

Four models were used at WES.

a. WES Implicit Flooding Model (numerical)

b. 1:100 Scale Model (physical)

c. 1:50 Scale Model (physical)

d. CELC3D circulation Model (numerical)

Refer to Technical Report CERC-84-5 included as Appendix G, for detailed discussions of all models used in this study.

WIFM Numerical Model

The WES Implicit Flooding Model (WIFM), a numerical tidal circulation model, was used to determine the tidal current field adjacent to Buhne Point. WIFM models the prototype bathymetry, bottom roughness, and inertial forces and takes into account the flooding and drying of low-lying terrain. Solving equations for fluid motion, WIFM identified maximum flood and ebb tidal currents to be used in the physical models. (See Figures 14 and 15.)

Proposed Phase III improvement plans, along with the groin and sandfill, were represented in the numerical model text, to determine the effects of the proposed project on the tidal current patterns. WIFM showed that changes in the tidal current velocities and flow patterns would be minimal everywhere in Humboldt Bay except near Buhne Point, where there was a one-foot per second decrease in the current speed.

1:100-Scale Physical Model

A 1:100-scale physical model of central Humboldt Bay included the jettied entrance to the bay, approximately 18,000 linear feet of shoreline inside the bay (including Buhne Point), and underwater contours throughout the central portion of the area between the jetties. (See Figure 16.) This model was used to determine wave characteristics in the vicinity of Buhne Point for a series of incident wave conditions, directions, various water levels, and tidal flow conditions. Statistical wave conditions at the entrance channel for the model were transformed from deep water by refraction-shoaling analysis using deepwater wave data from National Marine Consultants (1960)

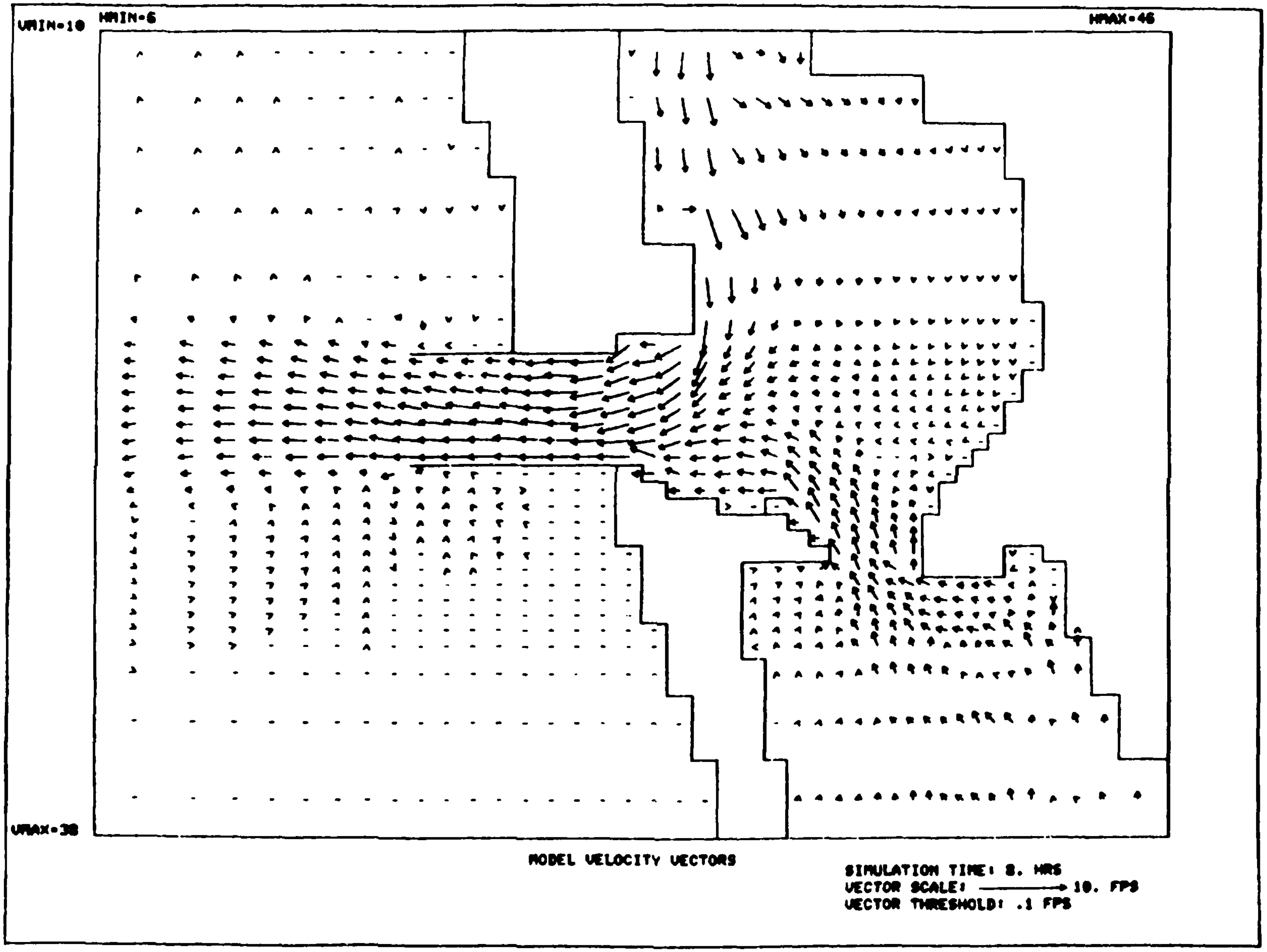

Figure 14. Flow Patterns At Maximum Ebb: Improvement Plan

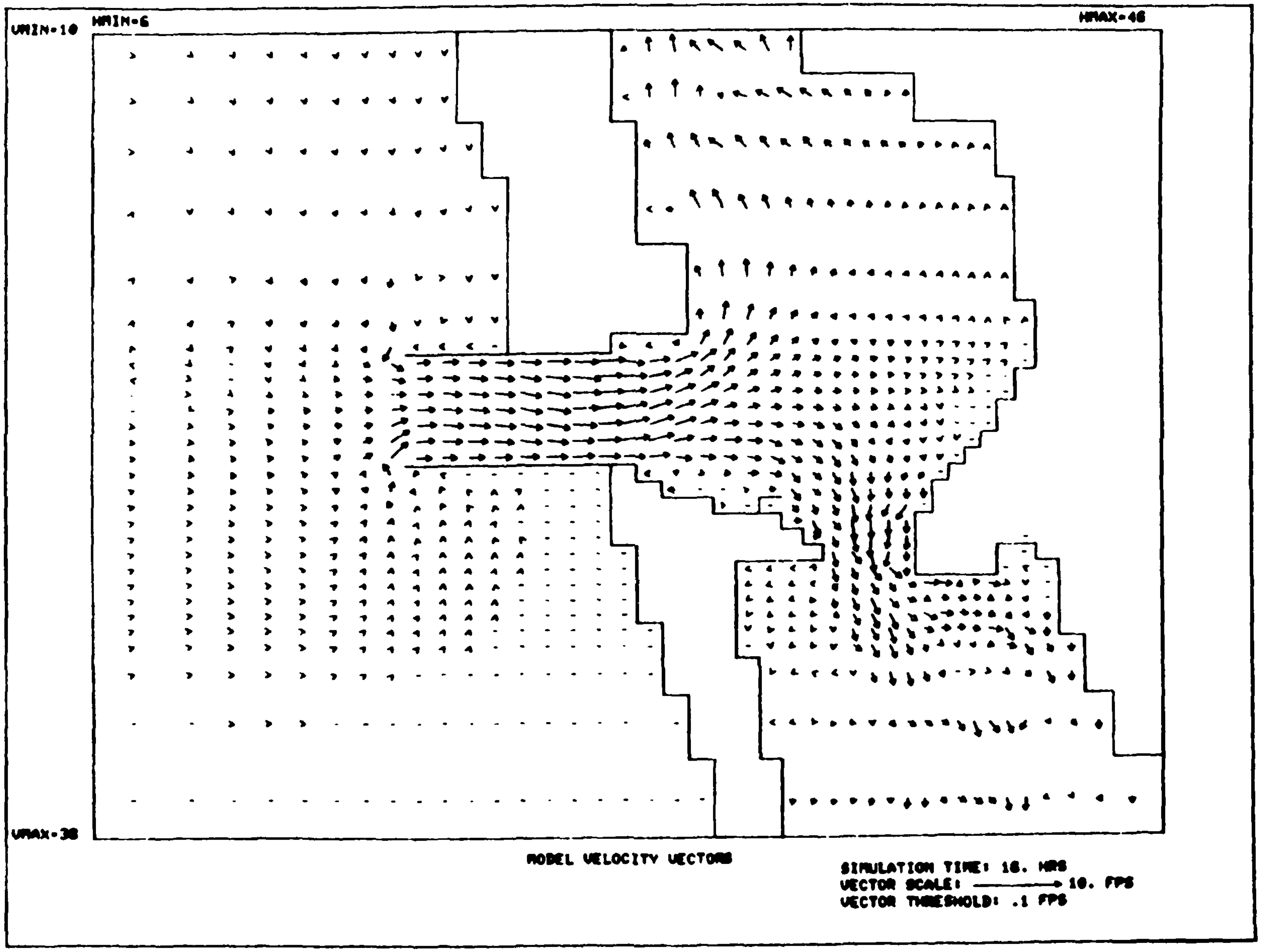

Figure-15. Flow Patterns At Maximum Flood: Improvement Plan

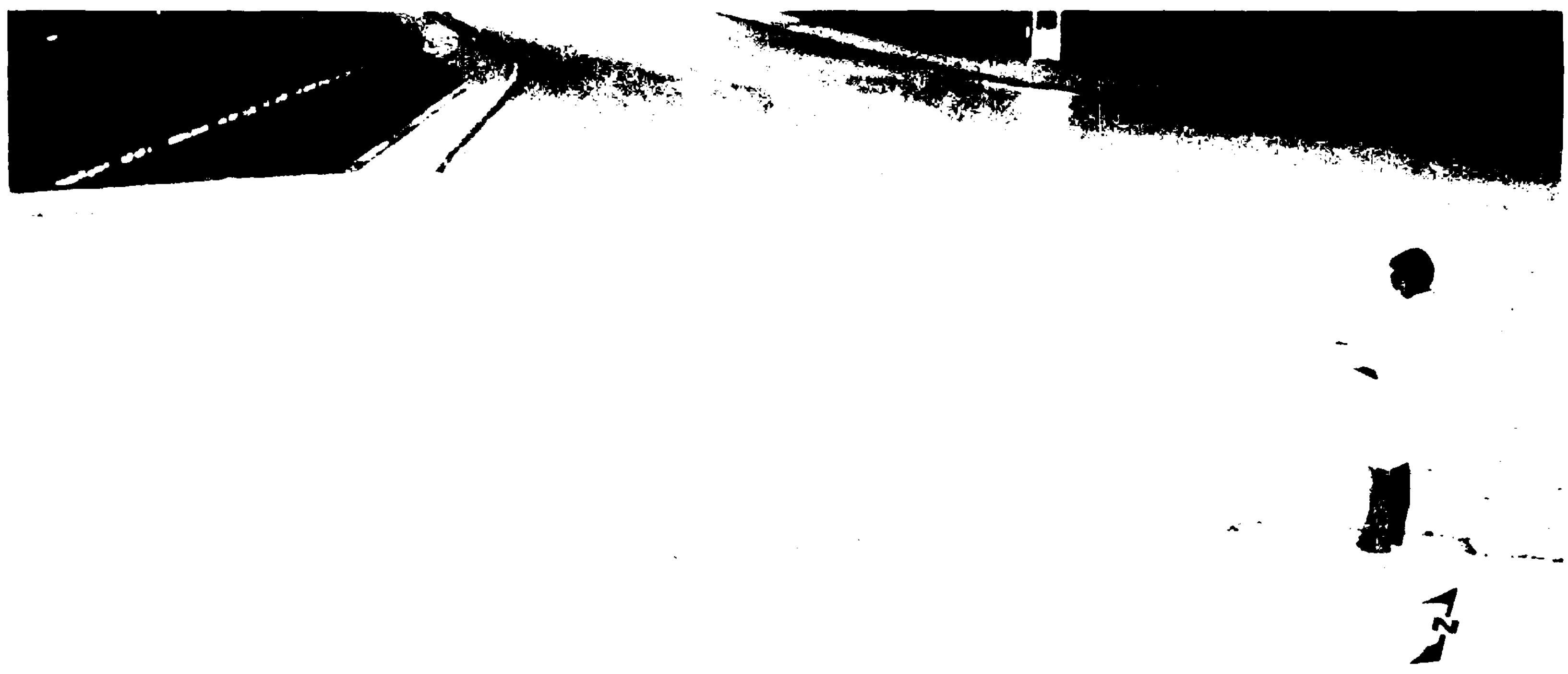

Figure 16. 1:100 Scale Physical Model.

and Department of Navigation and Ocean Development (1977). Based on the results of the 1:100 model study, the following were concluded:

a. Regardless of the direction of incident wave approach from the Pacific Ocean, the angle of the wave front in the vicinity of Buhne Point remains essentially the same.

b. Test waves from a northwest deepwater direction (approaching through the Humboldt Bay jettied entrance almost directly up the axis of the channel) result in significantly larger waves in the vicinity of Buhne Point, as opposed to test waves from the north and/or west.

c. The initial alignment of the Phase II sandfill is nearly coincident with the resultant wave forms approaching Buhne Point.

These results were used in the development of the initial alignments of the Phase III structures that were tested in the 1:50 scale model.

1:50-Scale Physical Model

The test conditions obtained from the 1:100-scale model were used as input into the 1:50-scale physical model of Buhne Point to evaluate the effectiveness of various structures proposed for shore protection. This model reproduced approximately 9,200 linear feet of shoreline in the Buhne Point area and the immediate underwater contours in Humboldt Bay. (See Figure 17.) The model utilized an 85-foot-long curved wave generator, a model tidal current circulation system, and crushed coal tracer material.

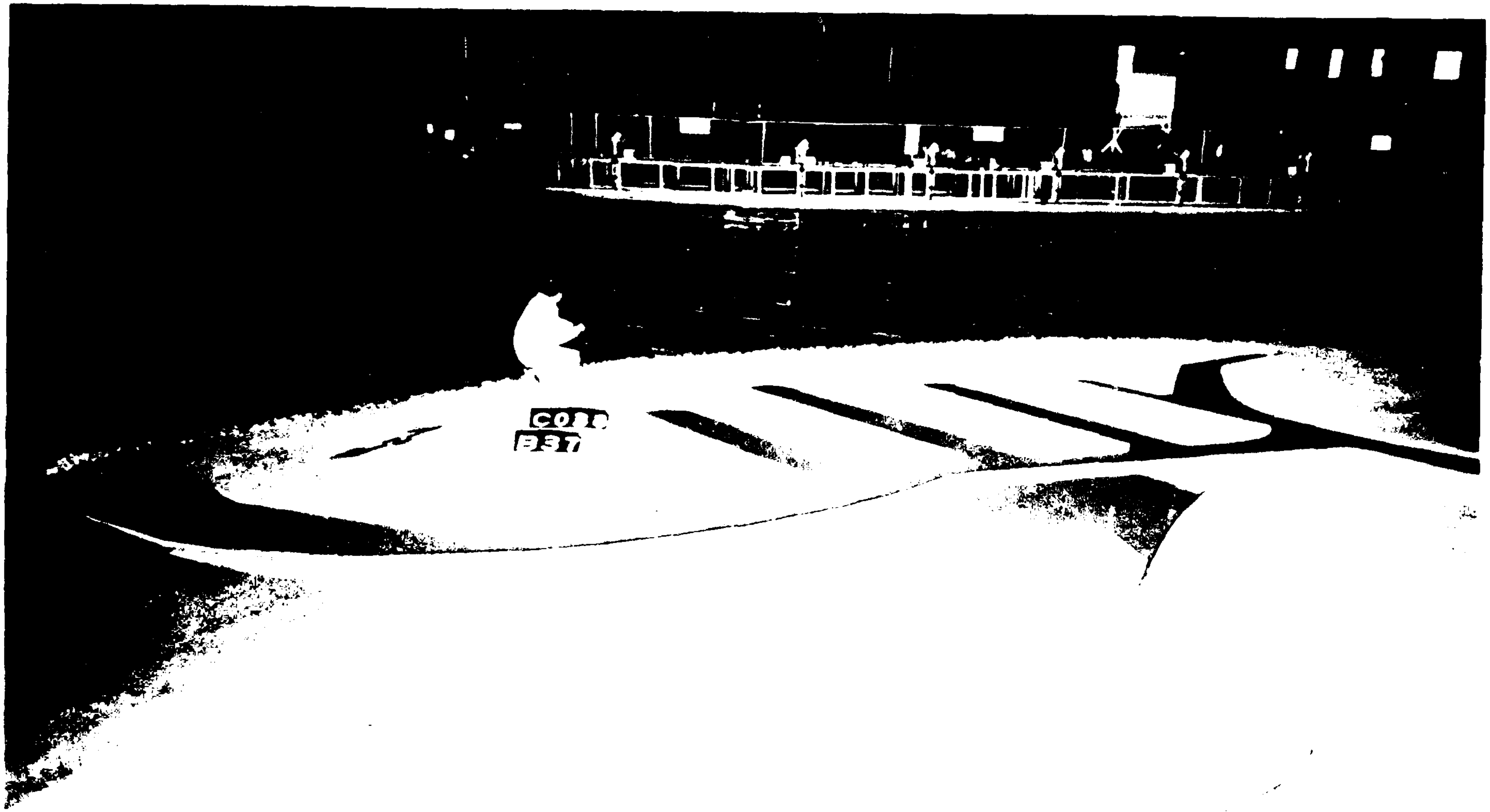

Figure 17. 1:50 Scale Physical Model.

Coal tracer tests began with the historical 1966 and 1980 shore configurations of Buhne Spit. The tests indicated that erosion of the spit began at the upcoast end with material migrating downcoast along the spit and eventually depositing into Fields Landing Channel.

It was evident that severe erosion at the north end of the spit was caused by the particularly high wave energy impinging on the local upcoast area. The downcoast end of King Salmon received a smaller amount of wave energy.

The next test plan conducted was the Phase I groin and Phase II sandfill configuration. The test showed a similar pattern of erosion as in the historical test. Erosion was quick upcoast at Buhne Point. Material migrated downcoast toward the Phase I groin and eventually around the groin into Fields Landing Channel.

Three conceptual Phase III plans were then tested: A groin field plan, a shore-connected breakwater plan, and an offshore breakwater plan.

The groin field plan (Figure 18) was tested, and resulted in erosion patterns similar to the historical and Phase I and II plan tests. Erosion in the upcoast groin compartments was severe as the material moved through, over and around the groins, with eventual movement offshore and around the Phase I groin into Fields Landing Channel. It was then apparent that longer and/or more groins would be required to stabilize the sandfill under the groin concept, which would greatly increase the cost. It was decided that either the shore-connected breakwater or the offshore breakwater would more efficiently reduce the wave energy at Buhne Point. Therefore, no further

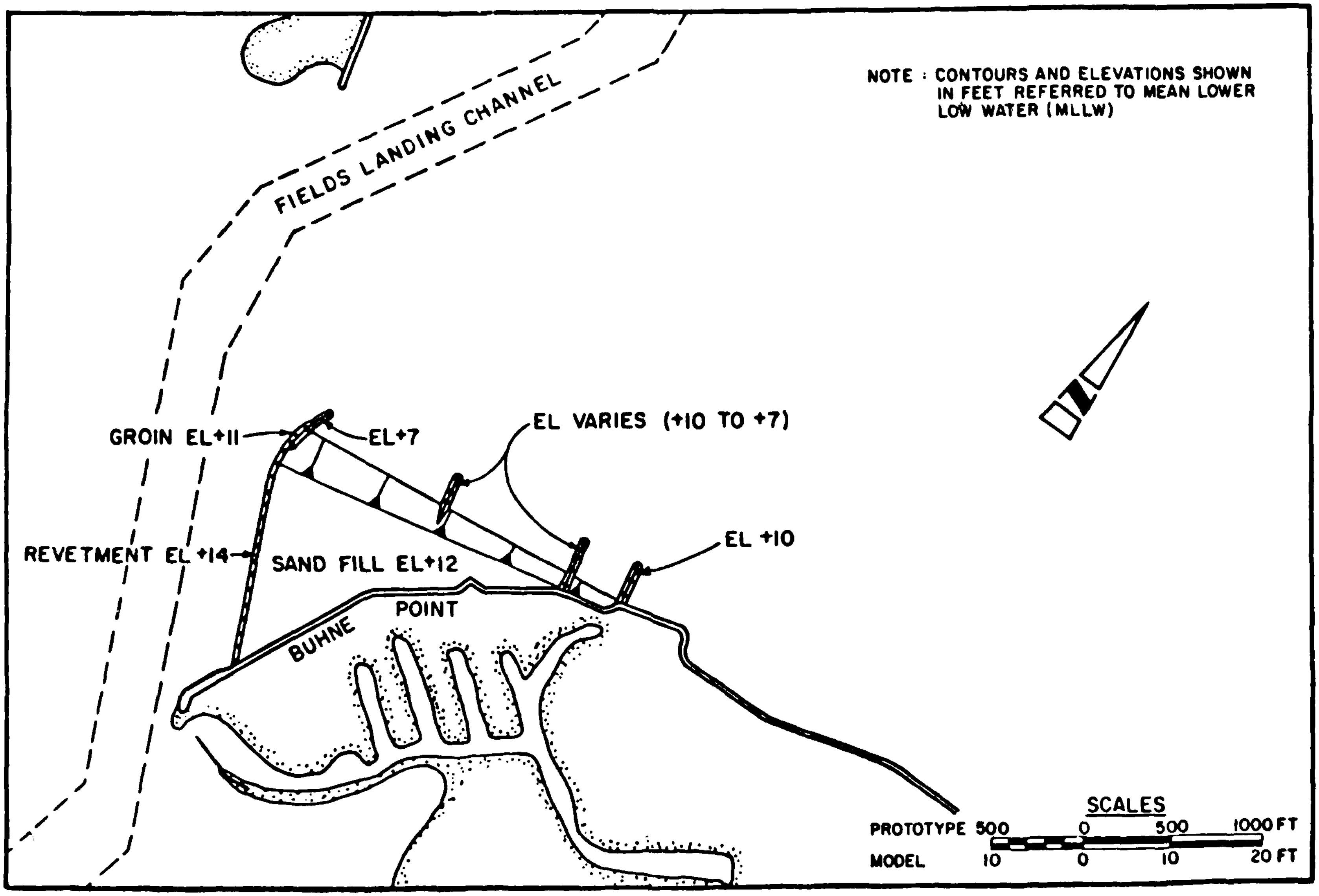

Figure 18. Groin Plan

testing of the groin plan was made, and the groin concept was abandoned.

The shore-connected breakwater plan (Figure 19) was tested, and a configuration that stabilized the sandfill was developed and optimized. This plan was comprised of a 425-foot (crest elevation +7 feet MLLW) extension to the Phase I groin and an 850-foot (crest elevation +13 feet MLLW) shore-connected breakwater at the upcoast end of the project. The breakwater tied into the existing revetment with a reverse curve trunk to disperse reflected waves that may affect other structures in the bay and to dissipate wave build-up along the trunk from a possible mach-stem effect.

The model showed that under the worst conditions tested (11-second, 10 foot test waves with a +9.5 foot still water level), the shore-connected breakwater minimized wave run-up and prevented wave energy from reaching Buhne Drive. Sediment in the lee of the breakwater remained stable, while the material in the wider fill area eroded to the east to accumulate toward the root end of the breakwater, or to the west to accumulate toward the head of the groin. While some material migrated through the rubble-mound head, the amount was negligible.

The trunk section of the breakwater was subsequently (Steering Committee Meeting #5, Eureka, CA; 25 Jan 1984, and in Progress Review Meeting, 30 Jan 1984; Vicksburg, Mississippi) moved upcoast approximately 250 feet extending the structure to 1050 feet. This configuration was established to provide additional protection to Buhne Drive and to allow for an enlarged area for sandfill between the landward side of the structure and Buhne Drive.

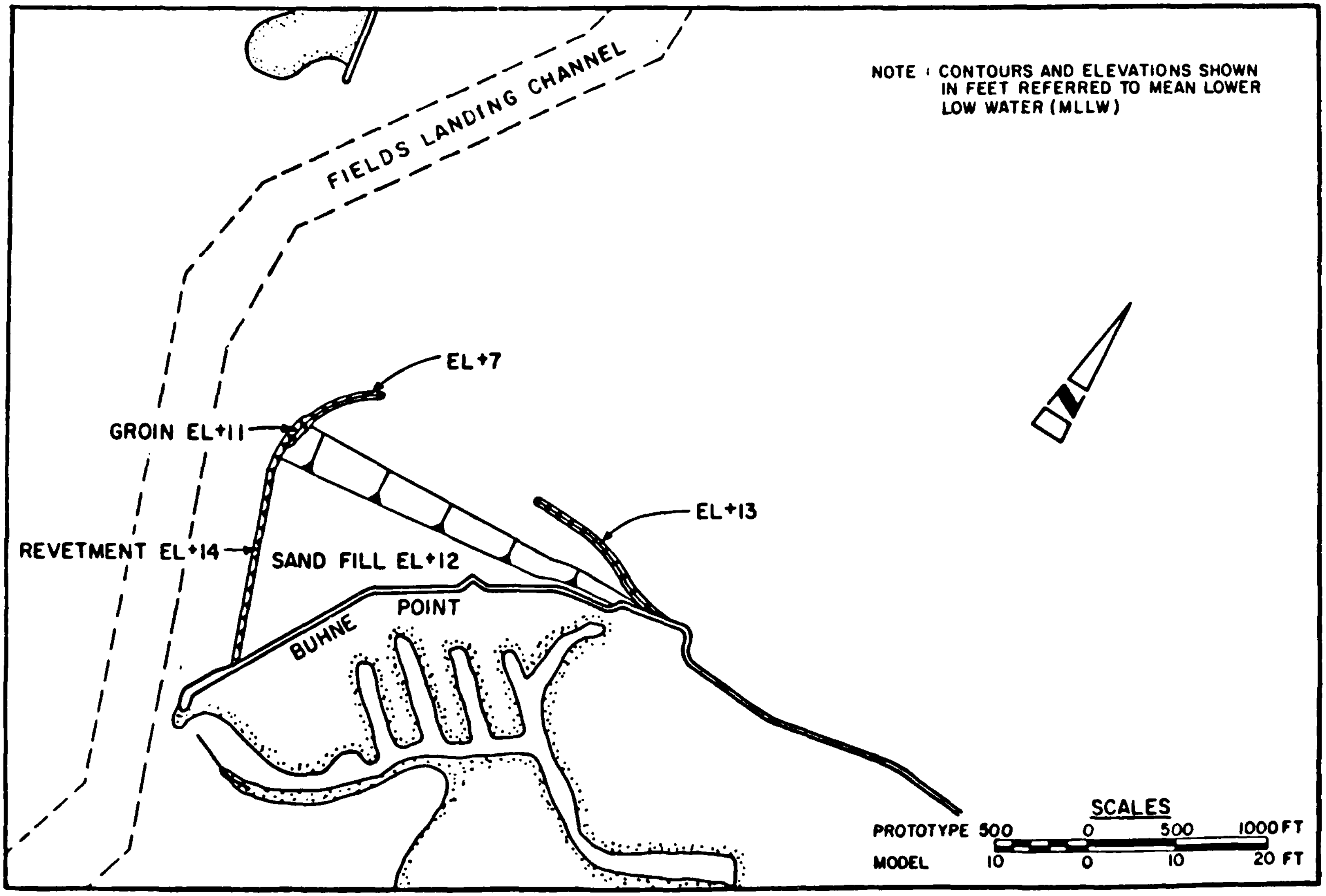

Figure 19. Shore-Connected Breakwater Plan

The offshore breakwater plan (Figure 20) was tested, and a configuration that acceptably stabilized the sandfill was developed. This plan consisted of a 1000-foot-long breakwater, with a crest elevation of +16 feet MLLW for 425 feet at the northeast end, +13 feet MLLW for 475 feet at the southwest end and a 100-foot transition between.

Model testing of this configuration showed that under the same severe test conditions, the sandfill remained generally stable. Some material moved westward to accomulate against the groin, and a small amount moved through the rubble-mound head. The shoreline would slightly rearrange, but would eventually stabilize. No runup on the overbank was observed on the lee side of the breakwater.

CELC3D Numerical Model

A numerical sediment transport model was used to evaluate the proposed improvements. The Coastal, Estuarine, and Lake Circulation Three-Dimensional model (CELC3D) was used to provide quantitative estimates of the hydrodynamic forces exerted on bottom sediments, and to identify regions where these forces would cause significant erosion or deposition. Based on the results of CELC3D, the patterns of erosion were identified for the with and without proposed improvements. It was concluded that:

a. Erosion occurs at Buhne Point largely due to wave action through the Humboldt jetties.

b. Eroded sediments tend to either linger between Buhne Point and the South spit or drift south into Fields Landing Channel.

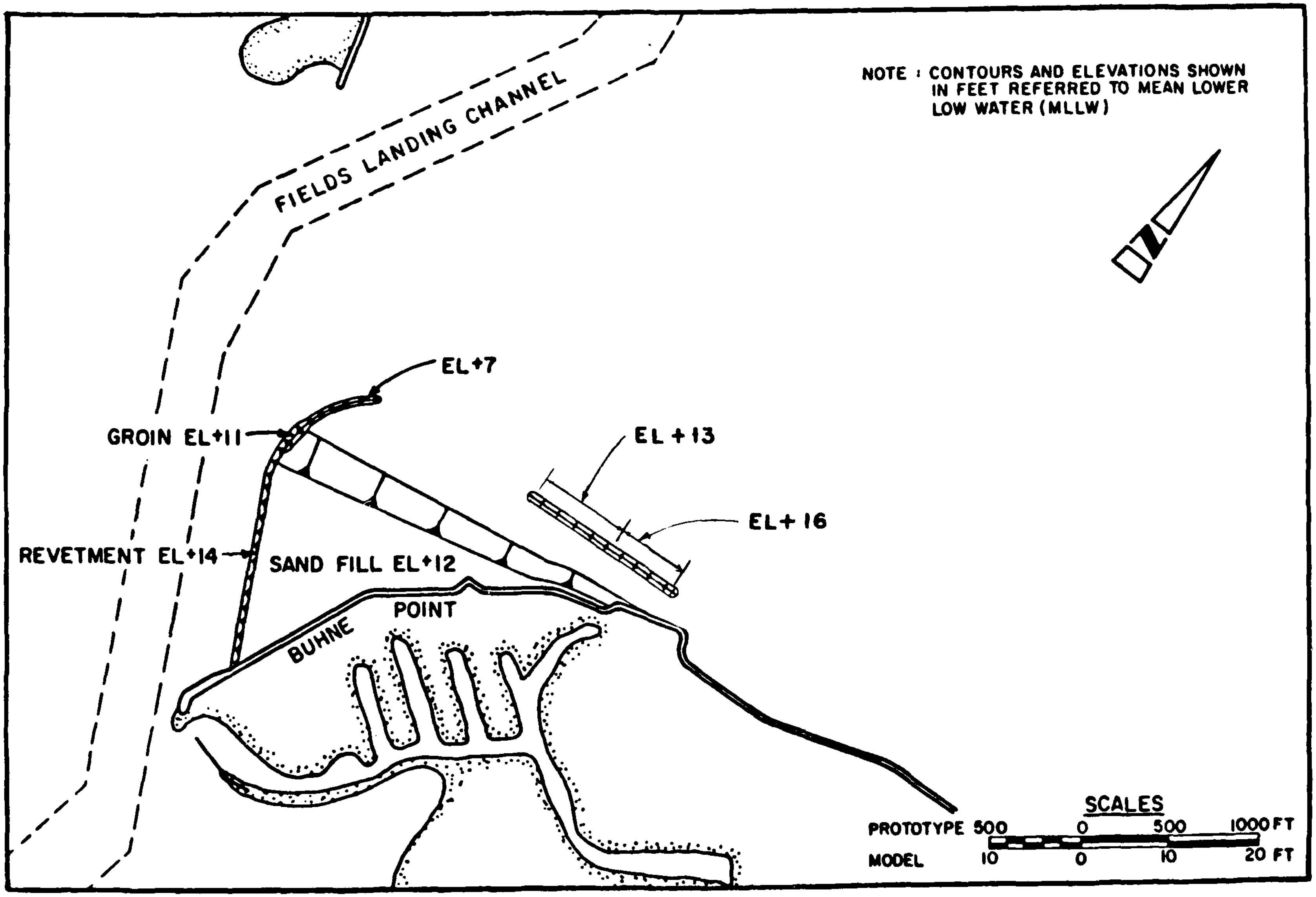

Figure 20. Offshore Breakwater Plan

c. The proposed improvements would neither alter sediment movements, nor induce any new erosion patterns.

Alternatives

Based on the model studies and subsequent discussions, (Steering Committee Meeting #5, Eureka, CA, 25 Jan 1984 and In Progress Review Meeting (IPR), 30 Jan 1984, Vicksburg, Mississippi) the following two plans were considered for selection:

a. <u>Plan 1-Construction of a 1050-foot Shore-Connected Breakwater at the Northeast End of the Phase II Fill</u>. The breakwater would be at an elevation of +13 feet MLLW with a 238-foot transition to the +18 feet MLLW PG&E revetment. About 700 feet of the breakwater's capstone would be grout sealed to prevent sand migration through the structure and to partially reduce wave and current energy transmitted through the structure.

b. <u>Plan 2-Construction of a 1000-foot Offshore Breakwater Located Approximately 300 Feet Offshore at the Northeast End of the Phase II Fill</u>. The northeast 475 feet of the breakwater would be built at +16 feet MLLW. The remaining length would consist of a 100-foot transition from +16 feet MLLW to +13 feet MLLW and 425 feet built at +13 feet MLLW.

Both Plans 1 and 2 include the following:

a. <u>A 425-Foot Rubblemound Extension (+7 Feet MLLW) of the Phase I Timber and Rock Groin</u>. This structure, as demonstrated in the model study, would stabilize the southwest portion of the sandfill from diffracted wave energy from the entrance channel and would retain the sand from migrating out of the fill and into Fields Landing Channel.

b. Grout Sealing of the Existing Phase I Rubble-mound Groin (150 Feet) and the Phase III Groin Extension. Sealing of the cover layers would prevent the migration of sand through the structures. This requirement was based on observations in the model study, experience with similar structures, and the fact that the groin extension would be subject to sand migration through the capstone.

c. Grading the Sandfill to +12 MLLW from +15 Feet MLLW and Forming Parallel Rows of Dunes (Elevation +14 Feet MLLW). Approximately 2000 linear feet of single sand fencing would be placed parallel to Buhne Drive as well. The sand fence would reduce aeolian transport of sand onto Buhne Drive and the residences in King Salmon.

d. Placing Approximately 1200 Feet of Revetment (Elevation +12 Feet MLLW) Along the Fields Landing Channel Side of the Timber Groin. The revetment would be placed on both sides of the timber groin from Station 10+00 to the rock head at Station 12+00. The revetment would provide protection to the sandfill when the timber baffles eventually deteriorate and become ineffective.

Plan Selection

The estimated construction cost of the two alternative plans were compared. The estimated costs were:

a. Plan 1 $3,100,000

b. Plan 2 $3,800,000

Plan 1 was selected because of the lower estimated construction cost. It was also anticipated that operation and maintenance cost would be less expensive for Plan 1, since land-based equipment could be utilized for possible repairs. Detailed cost estimates are contained in the Basis for Design Report included in Appendix F. Figure 21 shows the final project plan, and Figure 22 is an aerial photograph of the project taken in April 1985. The dark circular areas are patterns from irrigation sprinklers.

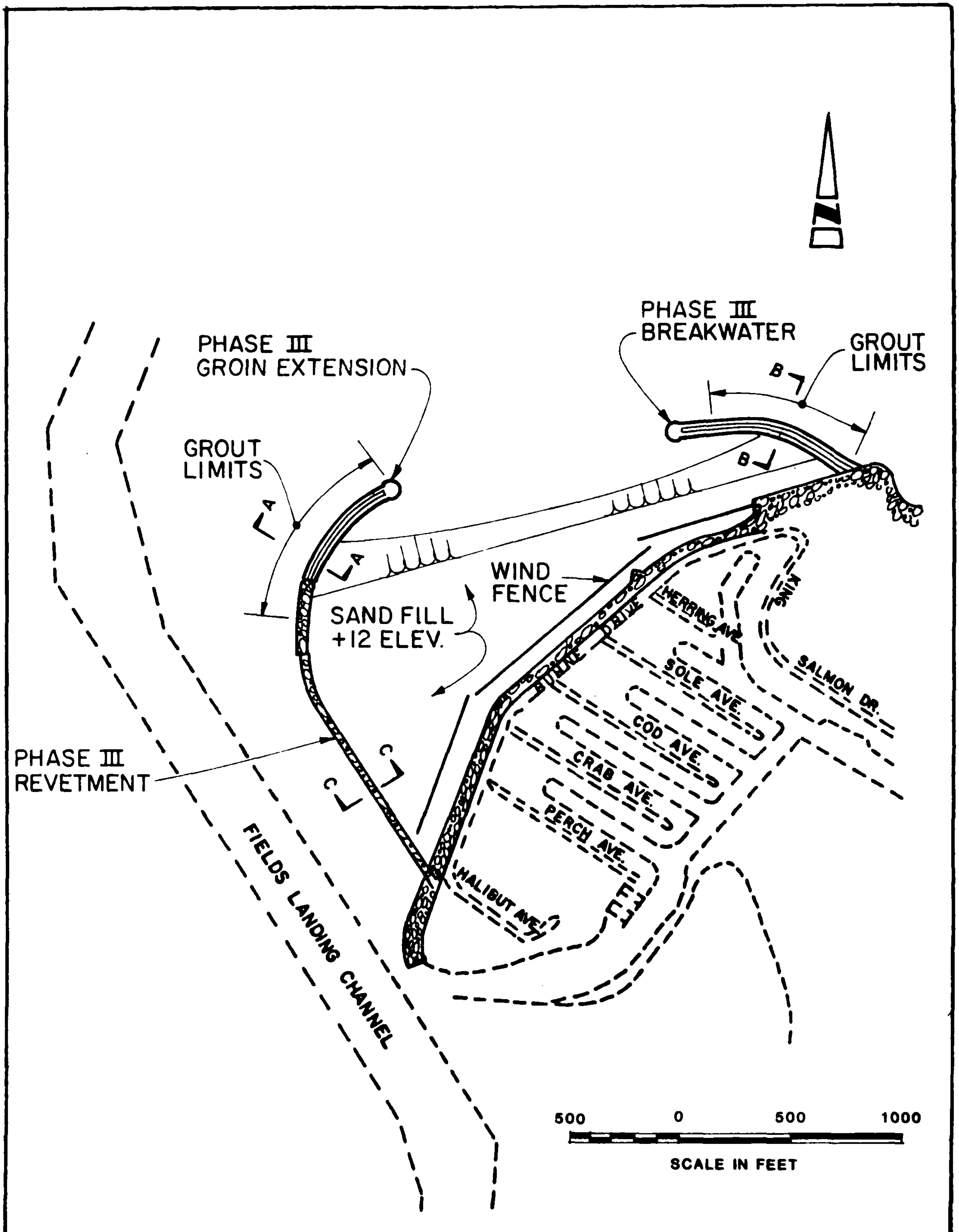

Figure 21. Phase III General Plan

Figure 22. Phase III Aerial April 1985.

PHASE IV

Plan of Study

Phase IV of the project was jointly conducted by the U.S. Army Corps of Engineers and the County of Humboldt Department of Public Works, and consisted of revegetation of the sandfill and a comprehensive 2-year monitoring program. The revegetation was designed to stabilize the sandfill against wind erosion losses utilizing native plants. The monitoring program was designed to document the performance of the project and its impact on the near-shore zone. This phase was not a part of the Department of Boating and Waterways' original recommended plan, but came about due to an objective set forth in the Memorandum of Understanding between the Corps and the FHWA.

Revegetation

The purpose of the revegetation program was to prevent sand loss from wind transport and by providing an attractive, low maintenance ground cover using native plant species. The sandfill placed during Phase II was contoured during Phase III to produce a series of low parallel ridges. (See Figure 23.) Live seeds and sprigs were collected from nearby native plant species and planted on the dune ridges and in the swales. (See Appendices B-D for Vegetation Collection, Planting and Monitoring Reports.) There were three phases of seed collection and planting during the period from 1985 to 1986. The revegetation program was developed by the Corps of Engineers, Los Angeles District and the County of Humboldt, and the work was conducted under the San Francisco District. A complete listing of species collected and planted can be found in the Seed Collection Reports included as Appendices B and C, and the Environmental Elements Report included as Appendix J.

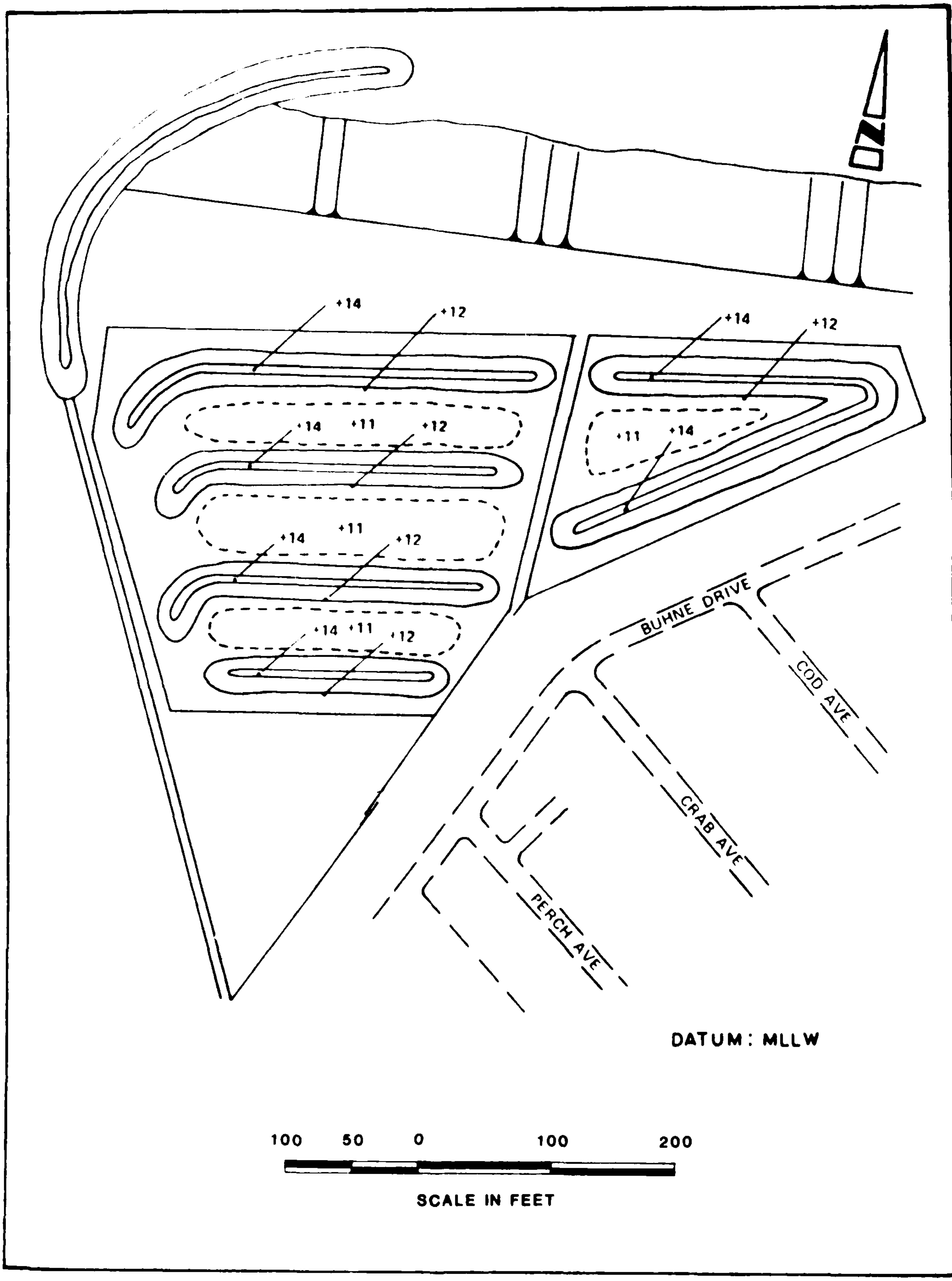

Figure 23. Plan View - Dune Elevations

Monitoring Program

The monitoring program consisted of two programs to better distinguish the effects of the project. The programs were physical and vegetative monitoring.

(a) Physical. The physical monitoring program consisted of twice-yearly hydrographic and topographic (aerial) surveys and soil samplings to detect volume changes and determine rates of sand movement on and around the sandfill. The physical monitoring also included a Littoral Environment Observation (LEO) program to monitor littoral transport as a result of wave action. The program was developed by the U.S. Army Corps of Engineers, Los Angeles District, and the work was conducted by the Los Angeles and San Francisco Districts.

Analysis of the physical monitoring data indicated that the project is performing as designed. The structures are functioning properly and the shoreline has evolved similar to that predicted in the model studies. Minor losses of sand due to wave action have occurred primarily during storms. Offshore of the replenishment spit, minor erosion has occurred since the project was constructed. The volume shoaled into Fields Landing Channel has apparently been reduced, however, shoaling patterns have remained essentially the same. Aeolian erosion has been reduced. The details of the physical monitoring program are described in the Monitoring Report included in Appendix H.

(b) Vegetative. The vegetation monitoring program, consisted of monitoring two study areas in the dunes to be revegetated. The areas were monitored for germination, development and survival. The purpose of the monitoring was to determine the effectiveness of different types of vegetation and planting techniques in creating a permanent stabilization cover for dunes. The program was developed by the U.S. Army Corps of Engineers, Los Angeles District, and the work was conducted by the County of Humboldt under contract with the San Francisco District. Results of the vegetation monitoring program are summarized in Appendix J. Detailed analyses of the monitoring data are shown in appendices B and C.

PROJECT COSTS

A summary of the project costs is presented in Table 1. The costs are separated into project management, engineering and design, and construction and field work (monitoring costs) for each major phase of work.

Table 1. Summary of Project Costs

	Project Management	Engineering and Design	Construction/ Field Work	Total
1. Initial Project Review	$ 382.00	$ 16,000.00	$	$ 16,382.00
2. Phase I Foundation Design	367.50	15,000.00	(1)	15,367.50
3. Phase II Sandfill & Groin Head	58,850.02	224,700.62	2,838,621.75(2)	3,122,172.39
4. Model Studies	5,937.49	374,999.53		380,937.02
5. Phase III	42,635.52	135,000.00	2,652,771.05	2,830,406.57
6. Road Reconstruction		47,380.00	532,766.00	580,146.00
7. Phase IV Vegetation	18,784.61	120,414.00	91,214.40	230,413.01
8. Phase IV Monitoring	34,329.89	65,000.00	58,679.07	158,008.96
9. Final Report	23,000.00	137,500.00		160,500.00
Total	$184,287.03	$1,135,944.15	$6,174,052.27	$7,494,333.45

(1)Phase I Groin Costs were $495,000 by the California Department of Boating and Waterways

(2)Includes $204,400 for cost of Phase I groin rubble-mound head.

Bibliography

California Department of Boating and Waterways, "Design Study for Buhne Spit/King Salmon Shore Protection Project at Humboldt Bay in the County of Humboldt," May 1983.

Humboldt Bay Symposium Committee, "Proceedings of the Humboldt Bay Symposium", Edited by C. Toole and C. Diebel, March 1982.

Humboldt County, "The History of Erosion at King Salmon-Buhne Point, Humboldt Bay, California from 1851 to 1985" February, 1985.

Johnson, J.W. and A.A. Kadib, "Sand Losses from a Coast by Wind Action." Proceedings, Ninth Conference on Coastal Engineering, ASCE, 1965.

National Marine Consultants, "Wave Statistics for Seven Deep Water Stations Along the California Coast," 1960.

Pacific Gas and Electric Company, "Meteorology and Atmospheric Diffusion in the Vicinity of the Humboldt Bay Power Plant," November 1965

State of California, "Views and Recommendations of the State of California on Proposed Report of the Chief of Engineers, Department of the Army, on Beach Erosion Control Report of Humboldt Bay (Buhne Point), California," July 15, 1957.

California Department of Navigation and Ocean Development, "Deep-Water Wave Statistics for the California Coast," February 1977.

U.S. ARMY CORPS OF ENGINEERS, "Humboldt Harbor and Bay, California." Unpublished, transmitted to Congress 1 July 1933.

U.S. ARMY CORPS OF ENGINEERS, Humboldt Bay, California. House Document No. 143, 82nd Congress, 1st Session, 23 October 1950.

U.S. ARMY CORPS OF ENGINEERS, "Soil Mechanics Design, Seepage Control." EM 1110-2-1901, 23 October 1950.

U.S. ARMY CORPS OF ENGINEERS, 5 October 1956. "Beach Erosion Control Report on Cooperative Study of Humboldt Bay (Buhne Point) California." Unpublished, transmitted to Chief of Engineers, 5 October 1956.

U.S. ARMY CORPS OF ENGINEERS, CHIEF OF ENGINEERS, "Appendix VI - Humboldt Bay (Buhne Point), California Beach Erosion Control Study." House Document No. 282, 85th Congress, 2nd Session, 24 July 1957.

U.S. ARMY CORPS OF ENGINEERS, LOS ANGELES DISTRICT, "Sealing of Mission Bay Jetties, San Diego, California," Circa 1958.

U.S. ARMY CORPS OF ENGINEERS, COASTAL ENGINEERING RESEARCH CENTER, Shore Protection Manual, ed ed., Vols. 11, 11 and 111, U.S. Government Printing Office, Washington, D.C., 1977, 1,262 pp.

U.S. Army, Corps of Engineers, Untitled. Engineering Technical Letter ETL 1110-2-292, 29 February 1984.

U.S. Senate, Interim Committee on Beach Erosion, Final Report - Transcription of Testimony, Hearing held August 16, 1954, Senate Resolution #39.

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